

# The V&V Agent's Role in the VV&A of New Simulations

## RPG Core Document

5/15/01<sup>1</sup>

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<sup>1</sup> This document replaces the 11/30/00 version. It contains minor editorial and formatting changes.

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## **VV&A Responsibilities & Challenges**

**“V&V Agent”** is the generic designation used throughout the VV&A Recommended Practices Guide (RPG) to describe the role that plans and performs the verification and validation (V&V) activities. Although different agents may be designated to perform different parts of the overall V&V effort (e.g., one for verification and another for validation), this practice is generally considered inefficient because it involves a separate learning curve for each agent and each accrues a separate knowledge and experience base. It can also make the start of validation extremely difficult at a critical time in the development effort. Thus, it is recommended that a single organizational entity be brought on in the beginning of the modeling and simulation (M&S) development process as the V&V Agent; additional personnel should be added as required for critical tasks that require special skills. The V&V effort can include the use of subject matter experts (SMEs) and outside agents who specialize in testing, analysis, or other necessary disciplines, depending on the type of M&S involved.

The objective of this core document is to discuss the V&V Agent’s role during the development of a new simulation.

### ***How Does the V&V Agent Impact a New M&S Development Effort?***

The major objectives of the V&V effort are to

- ensure that the simulation being developed meets the needs of the intended use
- reduce development and operational risk of the simulation
- enhance the simulation’s credibility
- support the simulation’s accreditation for the intended use

These objectives can best be realized through a cooperative arrangement between the Developer and the V&V Agent in which the V&V effort is executed in concert with the development of the simulation. The V&V effort needs to generate sufficient evidence to demonstrate that the simulation meets the stated requirements in terms of their associated measures and acceptability criteria. The body of evidence collected during development is essential in supporting accreditation of the simulation for use in a specified application. In addition, a sound V&V effort with well-documented products can extend and expand the life of the simulation by providing much-needed information about the capabilities, assumptions, limitations, and history of the simulation.

When the V&V effort is performed incrementally throughout the development process, interim development products can be collected, reviewed, and assessed and problems detected in a timely fashion. The identification of inconsistencies or inadequacies at

each stage in the development ensures that corrections can be made with as little impact as possible on development resources.

Studies have shown that failure to identify shortcomings in the requirements before they have been propagated through subsequent phases can increase correction costs by as much as a factor of 40 [Boehm (1981), Lewis (1992)]. Early and comprehensive detection of deficiencies is one of the high-payoff benefits of the V&V effort.

By providing information in step with development, the V&V Agent assists not only the Developer but also the M&S Program Manager (PM), whose job it is to ensure that the development and V&V efforts proceed on schedule and within budget.

### ***How Does a New Development Effort Impact the Way the V&V Agent Operates?***

In the development of a new simulation, the V&V Agent normally is designated by and reports to the M&S PM. This arrangement allows the M&S PM to coordinate the sharing of common resources between the development and V&V efforts whenever it makes sense to do so. Further, it allows the M&S PM to coordinate and leverage activities performed by the V&V Agent and others (e.g., Developer, Operational Test Authority (OTA)). The V&V effort is dependent upon many aspects of the development process: schedule; development paradigm; development approach (e.g., object oriented, structured); information, artifacts and products; tasks and tools. Ideally, the development effort will include a number of tasks that can be leveraged and tools that can be shared. Because the V&V Agent reports to the M&S PM, the M&S PM controls the flow of V&V information to the User and the Developer. This frees the V&V Agent to focus on the priorities established by the User and Accreditation Agent rather than being driven by the Developer or outside interests.

V&V activities are directed at improving the completeness, consistency, and correctness of the simulation and collecting evidence to support the accreditation assessment. Even though the V&V Agent reports to and takes direction from the M&S PM, the V&V information collected passes to the Accreditation Agent and User as a natural consequence of executing the V&V process. When the V&V effort is conducted in coordination with the development effort, information can be passed in an adequate and timely manner:

- the Developer is able to depend on the V&V Agent for timely assessment of the development activities and products
- the Accreditation Agent is able to receive a nearly continuous flow of evidence for the accreditation assessment
- the User is able to make decisions regarding possible modifications

- the M&S PM is able to make adjustments in schedules and resource allocations based on the User's decisions

Ultimately, the User ends up with a product that is much more likely to satisfy the intended application.

### ***What Are the V&V Agent's Responsibilities in Simulation Development?***

A properly conducted V&V effort helps establish credibility in the simulation, enhances its quality, increases its utility, and reduces overall program risk.<sup>1</sup>

- **Credibility**<sup>2</sup> is associated with whether the User believes the simulation is capable of accurately and appropriately reflecting the referent,<sup>3</sup> has sufficient quality for the intended use, meets the stated requirements, and works correctly and predictably.
- **Quality** of a simulation is associated with developmental issues, such as the detection and reduction of errors, deficiencies, poor design, and inadequate implementation. It also surfaces and records limitations and constraints of the simulation.
- **Utility** is a measure of the ability of the simulation to satisfactorily serve a variety of applications and uses.

Additional benefits of the V&V effort include

- reduction in operational defects
- more complete testing
- easier future reuse
- policy compliance
- reduced developmental and operational risk

**Development risks** are mostly addressed by verification activities that examine and assess the integrity, correctness, and completeness of the interim products, whereas validation focuses mostly on **operational risks** that relate to correctness of the interactions, behaviors, performance, accuracy, and predictability of the M&S in the context of its intended use. The result of a well-applied V&V effort is a much more usable M&S product that has higher quality and better reliability.

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<sup>1</sup> See the special topic on Risk and Its Impact on VV&A for additional information.

<sup>2</sup> Credibility is the relevance that the User sees in a model or simulation and the confidence that the User has that the model or simulation is fit for the specified purpose. [RPG Glossary]

<sup>3</sup> Referent: A codified body of knowledge about a thing being simulated. [RPG Glossary]

## ***What Challenges Does the V&V Agent Face Relative to VV&A?***

The following list identifies some of the major challenges associated with a V&V effort. Each is discussed briefly in the following paragraphs and additional information on some is provided in the specified appendices. .

- [Developing a Cooperative Relationship](#)
- [Establishing an Effective and Complete V&V Effort after a Delayed Start](#)
- [Creating an Adequate V&V Plan](#)
- [Determining Adequate Funding](#)
- [Selecting the Right People to Support the V&V Effort](#)
- [Ensuring the Availability of Development Products](#)
- [Acquiring the Right Tools](#)
- [Using Appropriate Techniques](#)
- [Coping with Geographic Separation](#)
- [Locating SMEs](#)
- [Understanding Acceptability Criteria and Accreditation Information Needs](#)

### **Developing a Cooperative Relationship**

The success of both the development and the V&V efforts is greatly dependent upon the ability of the V&V Agent to establish a good working relationship with all of the organizational entities: M&S PM, Developer, User, and Accreditation Agent; configuration management and quality assurance organizations; and any organic and independent test and analysis organizations involved.

### **Establishing an Effective and Complete V&V Effort after a Delayed Start**

The ideal time to begin a V&V effort is at the very beginning of the simulation development process, when the User has already made the decision to build a new simulation, has an approved program with committed funding, the M&S PM and Accreditation Agent have been designated, and the Developer is onboard. However, if the start of the V&V effort is delayed significantly, then the V&V Agent has to address the challenge of establishing a responsive and effective V&V effort while attending to the V&V activities. Because V&V activities build on the results of previous activities (e.g., requirements verification), the V&V Agent must ensure that these activities have been properly addressed. For more details, see [Appendix A](#).

### **Creating an Adequate V&V Plan**

When the V&V effort begins, the most fundamental task is the development of a V&V plan that defines the necessary activities to the level that they can be assigned to V&V

personnel and executed. The draft V&V plan may be prepared by the V&V Agent, with the concurrence from the M&S PM, Accreditation Agent, and Developer, or by the M&S PM with support from the Accreditation Agent and Developer. Either approach can work effectively with the cooperation of all parties.

To be effective, a V&V plan should be tailored to the specific situation. It should identify information needed to provide the best value to the User in terms of reducing risk and increasing confidence that the simulation will be fit for the intended use, identify the activities and tasks that will best produce that information, and determine an appropriate schedule for their execution. Because the V&V process works to reduce risk through constant examination and assessment of the development products and processes as they occur, the V&V plan should also be adjusted to fit the development schedule.. Other factors to be considered when developing the plan include staffing, subject matter experts (SMEs), validation data, working relationships, and techniques, and tools. For additional details, see [Appendix B](#).

### **Determining Adequate Funding**

The M&S PM and the V&V Agent should work together to determine the specific V&V tasks and the appropriate levels of effort required in each phase of the development. Because cost is a major factor in this decision, cost estimation is frequently a part of this effort. The cost-estimating process used should factor in complexity and size of the development effort and perceived risks and uncertainties to help refine the estimate. Other factors that have a significant effect on the estimate include

- availability and quality of data and development artifacts
- maturity and experience of the Developer
- stability of the requirements
- level of fidelity
- maturity of the technologies

The estimate should include other direct costs (ODCs) for such things as tools, hardware, support software, SMEs, and any other costs that are not included in the direct labor figures.

Once an adequate estimate is derived, the M&S PM and V&V Agent should negotiate the funding of the V&V effort. This may require some compromises from both parties. Underfunding can be a significant problem since it invariably results in compromises and, if severe, can jeopardize needed activities. For more information, see [Appendix C](#).

### **Selecting the Right People to Support the V&V Effort**

A successful V&V effort requires skilled and experienced participants. To identify the types of skills, experience, and knowledge needed, the V&V Agent should have a

thorough understanding of the intended use and the general requirements of the M&S program. However, not all of the required skills have to be available on every day of the program. In fact, it is quite appropriate in the V&V plan to identify the specific skills needed during each activity so the personnel can be brought in as needed. The core V&V effort can also be supplemented by SMEs and other personnel, as required. For additional details, see [Appendix D](#).

## **Ensuring the Availability of Development Products**

Another important success factor is the timely availability of development artifacts, data, and products, which depends on the responsiveness of the Developer. A few key things need to occur for this to work effectively:

- The M&S PM should establish a contractual relationship between the Developer and the V&V Agent (i.e., the contracts should specify what products should be produced and who should have access to them).
- The V&V Agent should identify what development artifacts and products will be needed at each phase of the development, should define how the reviews and assessments will be handled, and should identify what V&V products will be provided in return.
- The Developer should understand that the V&V effort is a resource and not an obstacle. The V&V effort is done to improve the quality of the development products and increase the likelihood that the simulation will satisfy the User's needs and meet the acceptability criteria.
- The V&V Agent needs to establish a relationship of trust with the Developer and avoid becoming confrontational. The V&V effort should make a favorable impact on all the products it reviews and assesses, and provide prompt, constructive feedback to the Developer and M&S PM, as required.

## **Acquiring the Right Tools**

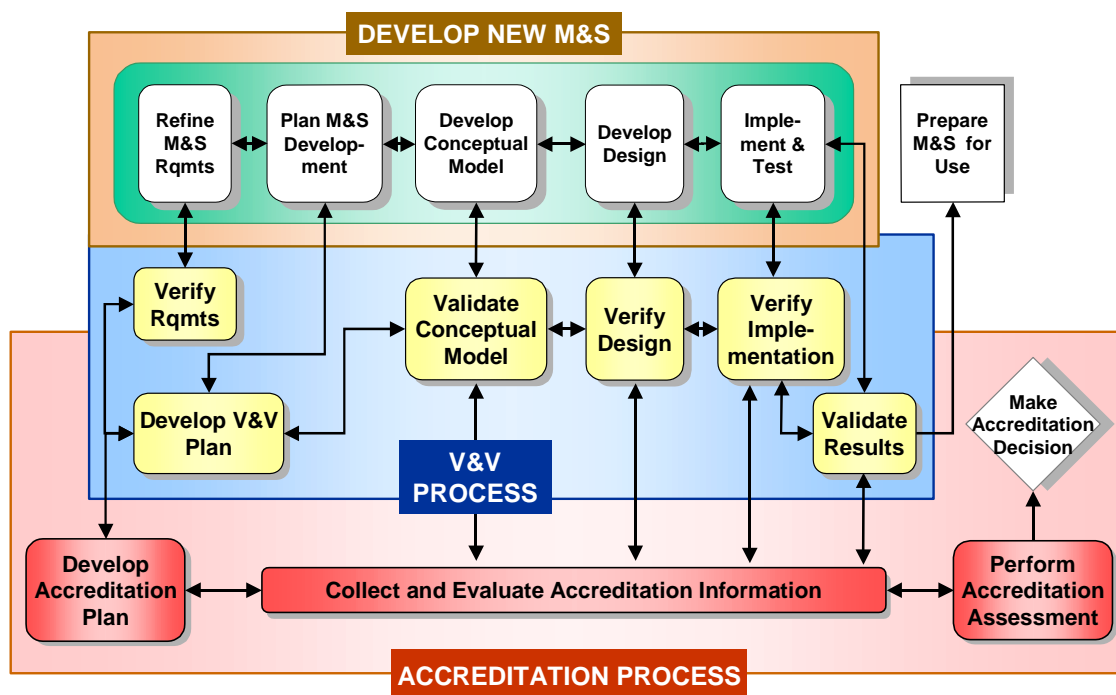
Numerous tools are available to facilitate V&V activities, but the V&V Agent has to begin with a good understanding of the development effort before the process of selecting tools can begin. The basic program characteristics that influence V&V tool selection include the development paradigm, approach, schedule, environment, tools, and integration and test approach. Once the V&V Agent has this knowledge, a basic set of V&V tools can be identified for consideration, and then a cost-benefit analysis can be done to assist in making the final selection. Several of the key factors include compatibility with Developer's tools, cost, training, availability and maturity, flexibility, and required accuracy and capabilities. The best tools for V&V efforts are often the smaller, easier-to-use, cheaper tools that respond better to quick reaction assessments than the more elaborate, highly integrated development environments and tools, which



are more effective for development.<sup>4</sup> Additional information can be found in [Appendix E](#).

## Using Appropriate Techniques

The basic V&V process for new simulations consists of a set of activities that correspond to the development phases shown in the diagram below. Each of these V&V activities consists of a number of tasks that be tailored to meet the particular needs of each project. The tasks themselves are selected and the techniques used to perform the tasks are chosen based on the needs of the program. The technique chosen for a particular task depends on the importance of that task to the overall program, the risks involved, and the priorities established by the User.<sup>5</sup>



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## Coping with Geographic Separation

When the Developer and the V&V Agent are located in different places, building and maintaining the necessary level of interaction and trust is more difficult. The V&V Agent and Developer should be near each other (within 50 miles) whenever possible; however, when separation cannot be avoided, the M&S PM should establish a V&V

<sup>4</sup> See the reference document on V&V Tools for additional information.

<sup>5</sup> See the reference document on V&V Techniques for a synopsis of standard techniques.

liaison in the Developer's facility to help facilitate information exchange. Alternatively, members of the V&V team may alternate on extended temporary duty (TDY) tours with the Developer.

Fortunately, information and data can be transferred across the country as easily as across a room. Teleconferencing and e-mail allow frequent exchange of information and can be used in lieu of some meetings, but face-to-face meetings are essential at times and people will have to travel. Careful planning and coordination and the presence of a V&V liaison can help reduce the need for frequent travel.

## **Locating SMEs**

A major challenge to the V&V Agent is identifying and locating subject matter experts (SMEs) to assist at critical points in the program. A common need is for experts in the problem domain and user domain associated with the application to assist with requirements verification and conceptual model validation. The User community is usually the best source for experts in the problem domain, and the sponsoring User can often either supply these people or make good recommendations about whom to ask and how to secure their help. Additional expertise may be needed in other areas, such as simulation design, programming languages, data, and software engineering.

SMEs should have strong backgrounds in their specified area, whether military tactics, cloud physics, chemical engineering, or object-oriented programming. Additional selection criteria include<sup>6</sup>

- formal training in operations research or related analytical disciplines availability
- interest in the project
- experience
- ability to support the effort for the specified times

## **Understanding Acceptability Criteria and Accreditation Information Needs**

Acceptability criteria are the standards that the simulation must meet to be accredited for a specific purpose. They are normally derived by the User and Accreditation Agent with support from the M&S PM and SMEs during analysis of the problem.<sup>7</sup> The M&S requirements<sup>8</sup> are examined and appropriate metrics (the units by which they are to be measured) and acceptability criteria (the standard for success) are assigned. A risk assessment<sup>9</sup> is also done to determine which requirements are most important to the success of the application. The V&V Agent and Accreditation Agent should meet as early in the process as possible to discuss the acceptability criteria, how they were

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<sup>6</sup> See the special topic on Subject Matter Experts and VV&A for additional information.

<sup>7</sup> See the special topic on Problem Analysis for additional information.

<sup>8</sup> See the special topic on Requirements for additional information.

<sup>9</sup> See the special topic on Risk and Its Impact on VV&A for additional information.

derived, how likely they are to change, what types of information are needed to support accreditation, and V&V priorities (i.e., which issues should be addressed first and what level of effort should be focused on each). Note that acceptability criteria may be more fully defined or additional acceptability criteria may be identified during this discussion, especially when new technology is involved.

The M&S PM should work with the V&V Agent and Accreditation Agent to ensure that the V&V effort can provide the information needed for the accreditation assessment and to ensure that the V&V plan includes appropriate tasks. The M&S PM should also bound the scope of the V&V effort to ensure that the information and evidence needed to support the Accreditation Agent will be met.<sup>10</sup> For additional information, refer.

## Role of the V&V Agent in the Overall Problem Solving Process

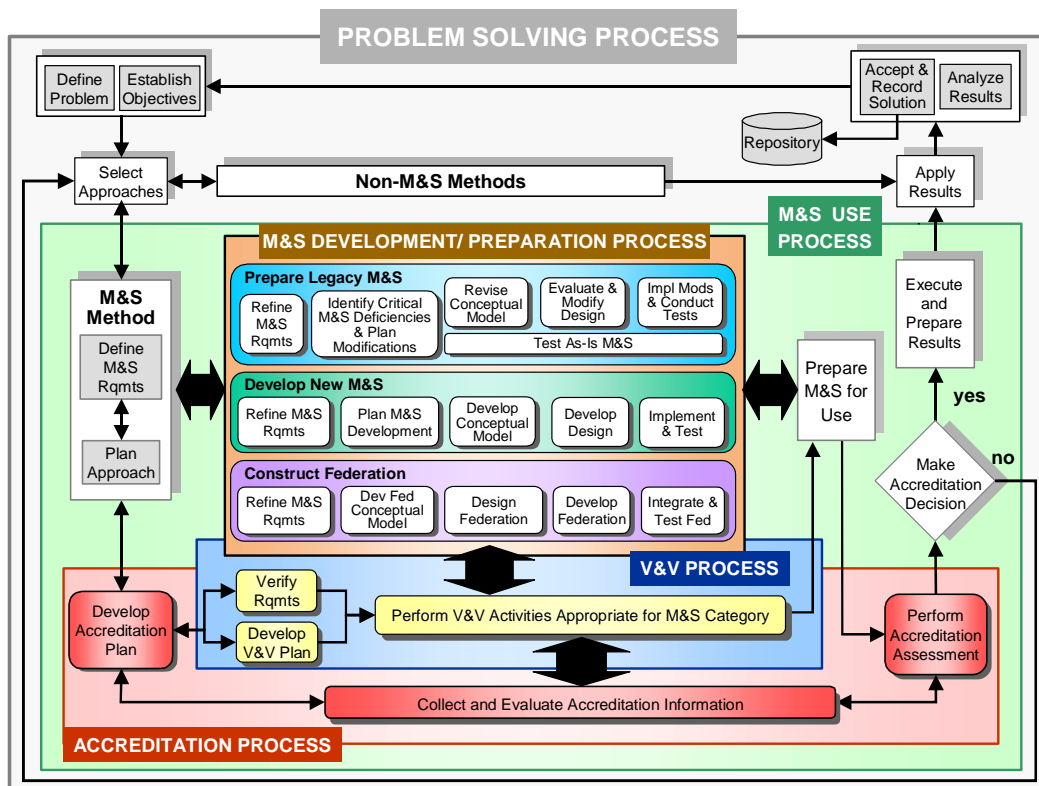
### *Problem Solving Process*

Full understanding of how the V&V process interacts with the development of a new simulation requires an understanding of the overall problem solving process. The problem solving process diagram shown below depicts the relationships between the **Problem Solving Process**, **M&S Use Process**, **M&S Development/Preparation Process**, **V&V Process**, and **Accreditation Process** as a series of nested boxes. Each nested process contains a series of individual boxes that represent the basic individual activities, functions, and sub-processes considered essential to complete that process. The **Problem Solving Process** is the outer-most box in which the entire process begins and ends.

The overall problem solving process is the province of the User. The User initiates the entire process by first defining the problem and establishing the objectives and then by selecting the method or methods to resolve it (e.g., modeling and simulation, experimentation, statistical analysis, live testing). The User concludes the process by applying the methods (e.g., making the decision to accredit the simulation for use, running the simulation, accepting the simulation results) and analyzing, accepting and recording the overall solution. How well these activities are performed, particularly those at the beginning, is critical to the success of the entire process.

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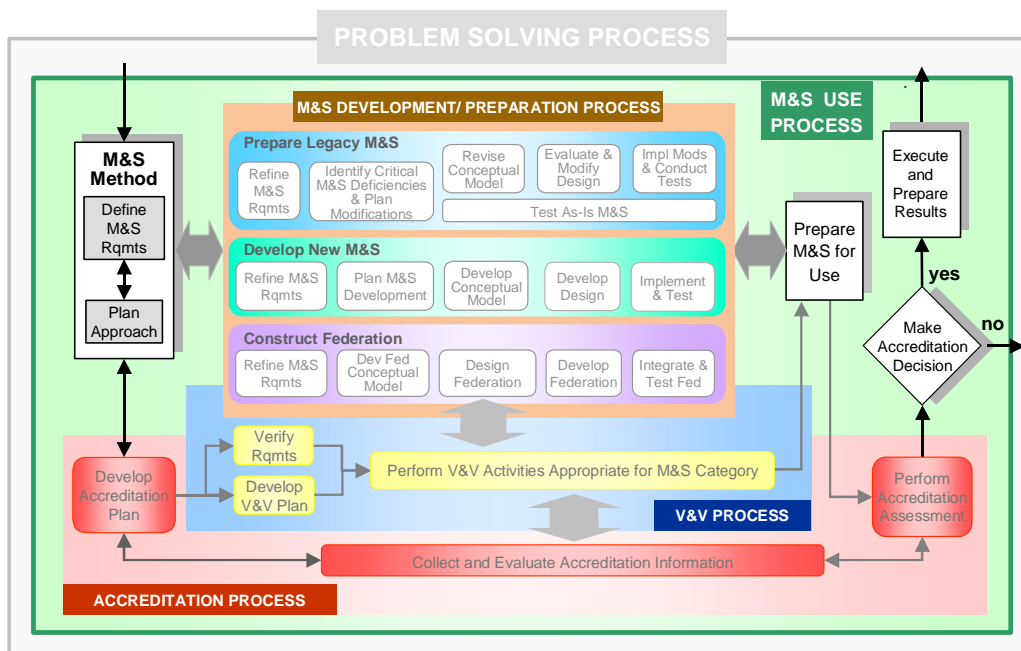
<sup>10</sup> See to the core document on Accreditation Agent Role in the VV&A of New Simulations for additional information.



The Overall Problem Solving Process

## M&S Use Process

Once M&S has been selected as the method to use, the first nested process in the Problem Solving Process, **M&S Use Process** shown below, begins.

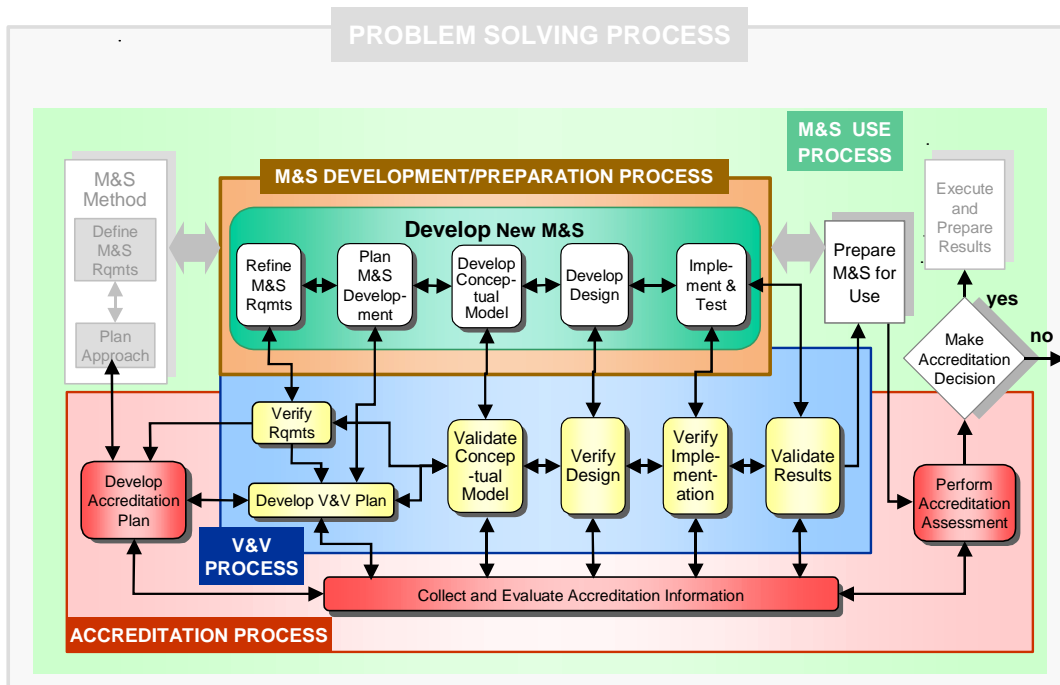


M&S Use Process in the Problem Solving Process

The first phase in the M&S Use Process diagram above, **M&S Method**, is perhaps the most critical for successfully meeting the application objectives because the tasks and activities performed and the decisions made during this phase lay the foundation for a disciplined development process and a tailored and supportive VV&A effort. During this phase, the M&S PM and Accreditation Agent are designated and they join the User in defining the M&S requirements, identifying the associated metrics and acceptability criteria, assessing the risks, and establishing priorities. The M&S PM also designates the Developer and V&V Agent.

## **M&S Development/Preparation Process**

The next nested process, **M&S Development/Preparation Process** begins when the M&S PM designates the Developer. The M&S PM and Developer define the development profile, select the development paradigm, establish the development schedule, and initiate the plan. Regardless of which development paradigm<sup>11</sup> is followed, the development process for new simulations consists of the six basic phases shown in the diagram below (see also the [VV&A in New M&S Development](#) figure [p. 7]).



### **M&S Development/Preparation Process for New M&S**

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Associated with each development phase is a corresponding V&V activity that examines and tests the progress in that phase, provides timely feedback, and collects

<sup>11</sup> See the special topic on Paradigms for M&S Development for additional information.

evidence of the simulation's capabilities to be used in the accreditation assessment. These are discussed in the section below.

## **VV&A Functions of the V&V Agent Role in New M&S Development**

This section begins with a discussion of the basic differences between verification and validation and how they work together in the V&V process. Next is a discussion of each of the six basic activities that make up the V&V process for new simulation development followed by a discussion of other considerations.

- [Differences Between Verification and Validation](#)
- [Verify Requirements](#)
- [Develop V&V Plan](#)
- [Validate Conceptual Model](#)
- [Verify Design](#)
- [Verify Implementation](#)
- [Validate Results](#)
- [Other Considerations](#)

### ***Differences Between Verification and Validation***

In M&S, the terms verification and validation have specialized meanings. Perhaps the easiest way to distinguish between verification and validation is to examine the definitions of the two terms and consider how the two processes work together to accomplish their primary goals.

#### **Verification**

**Verification** is the process of determining that a model implementation and its data accurately represent the Developer's conceptual description and specifications [DoD Instruction 5000.61]. In simulation development, verification is usually an iterative process which determines that a model and its resultant simulation accurately represent both what the contract requires and what the M&S Developer said would be built in accordance with those requirements. Because verification is most effective when performed in step with the development phases, basic verification activities are frequently referred to by the type of development activity involved (e.g., requirements verification, design verification, implementation verification). Verification activities are done to ensure that the simulation will have complete and consistent requirements, a well-defined conceptual model, a more thorough and correct design, and an

implementation with far fewer operational problems than would otherwise be the case. The verification effort should result in greater understanding of the simulation's hardware and software configurations, higher quality development products, fewer issues unresolved or left to chance, lower development risk, easier reuse and maintenance, and a more satisfied User.

## Validation

**Validation** is the process of determining the degree to which a model and its associated data accurately represent the real world from the perspective of the intended uses of the model [DoD Instruction 5000.61]. Validation examines how the simulation will be used to determine if the amount and degree of detail represented provide the degree of correspondence with the real-world phenomena (i.e., the referent)<sup>12</sup> necessary for the simulation to be used with confidence. Validation is aimed at establishing the overall credibility of the simulation for a given application, including the appropriateness and accuracy of the conceptual model, individual components, and outputs. Where verification activities tend to be named for the development phase they pertain to, validation activities are named for the product being validated (e.g., conceptual model, data, results). In its simplest form, validation consists of comparing a prediction (e.g., results from the simulation) to an observation (e.g., referent) and making a judgment about whether the two are close enough to satisfy the needs of the application. This category of validation is generally considered "results validation" and occurs mostly toward the end of the development period. Although validation is firmly grounded in testing, it also often includes sensitivity analysis, comparisons to other models and simulations, and opinions of SMEs. See the special topic on Validation for more information.

## How Verification and Validation Work Together

Verification asks, "Did I build the model correctly?" Validation asks, "Did I build the correct model?" The two processes work together sequentially. Verification ensures the logical integrity of the product at each step, so that validation can focus on the sufficiency of the operational and representational aspects of the simulation. Thus, validation determines whether the interactions, responses, and capabilities present in the behaviors and representations are sufficient to carry out the required missions, functions, and operations. Validation reduces the operational risk, improves the thoroughness of testing, increases the User's confidence in the product, and perhaps most important, greatly enhances the overall credibility of the simulation.

## Verify Requirements

As depicted in the [VV&A in the New M&S Development](#) diagram (p. 7), the **Verify Requirements** and **Develop V&V Plan** activities are essentially concurrent processes. Their initiation is often dependent upon the terms of the contractual agreement. In

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<sup>12</sup> A codified body of knowledge about a thing being simulated.



some cases, a draft V&V plan is prepared as part of the proposal and is only finalized after the requirements are well understood and requirements verification is underway.<sup>13</sup> This practice ensures that the resulting V&V plan, and the resulting V&V effort, is better tailored to the needs of the application.

The early focus of both the development and V&V efforts is on refining, expanding, and verifying the M&S requirements.<sup>14</sup> It is difficult to generate a detailed V&V plan before the requirements are at least somewhat stable and mostly defined, since the requirements define the size, complexity, fidelity, scope, entities, and characteristics of the M&S to be built. The V&V planners need to know a great deal about the M&S to estimate the job that lies ahead. They also need to determine how the software and hardware will be configured and developed, tested, and assessed.

M&S requirements include all the requirements from the user and problem domains of the specified application, as well as the requirements from the simulation domain (e.g., operating requirements) that are derived from them. The User is responsible for defining the user and problem domain requirements; the Developer should work with the M&S PM to define simulation domain requirements based on the needs of the application.

During M&S requirements definition and refinement, the User normally conducts a problem analysis<sup>15</sup> (supported by the M&S PM, Developer, Accreditation Agent, SMEs, and the V&V Agent when available). This analysis examines the M&S requirements to identify metrics and acceptability criteria for each and determines if additional clarification, enhancement or decomposition is needed. It is normally followed by a risk assessment to identify and prioritize the risks associated with the development and use of the simulation (see the discussion on [risk and uncertainty](#) under Planning Considerations [p. 20]).<sup>16</sup>

Although requirements verification should be accomplished as early as possible to ensure a proper foundation for the development effort, this activity may have to be revisited throughout the development process as more detailed information becomes available or when changes occur that impact the requirements and objectives of the application.

Requirements verification should be conducted to ensure that

- M&S requirements fully address the User's requirements
- M&S requirements are defined with sufficient detail to be readily represented in the simulation

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<sup>13</sup> In this case, requirements verification may be performed by SMEs under the direction of the User or Accreditation Agent.

<sup>14</sup> See the special topic on Requirements for additional information.

<sup>15</sup> See the special topic on Problem Analysis for additional information.

<sup>16</sup> See the special topic on Risk and Its Impact on VV&A for additional information.



Verification of the requirements is an essential V&V task and should be revisited throughout the development effort. The initial requirements verification effort focuses on identifying the correctness, consistency, and completeness of the requirement definitions and on reviewing any source documentation to ensure that the requirements imposed on the simulation are adequately defined. Subsequent efforts focus on ensuring that any changes to the requirements (e.g., decomposition of existing requirements to provide the necessary level of detail, the addition or removal of requirements) are verified and that the requirements are appropriately reflected in each phase of the development. Requirements verification results should be submitted to the M&S PM for review, approval, and distribution.

## Requirements Verification Tasks

[click to review VV&A in New M&S Development](#) page 7

Requirements verification involves a number of different tasks, such as those listed below. The specific tasks and the level of effort associated with each should be tailored to meet the needs of the current application.

### Verify Requirements: *Review M&S Requirements by Domain*

The M&S Requirements is the set comprised of the requirements originating from the problem domain, user domain, and simulation domain. The user and problem domain requirements are essentially independent of the simulation, although they impose many features, constraints, and capabilities on its implementation. The user domain requirements and the problem domain requirements should be compared to identify any inconsistencies and omissions.

#### Example:

If the problem involves evaluating the capability of different target acquisition (TA) systems in a jungle environment, then the problem domain should include requirements on the relevant characteristics of each TA system and platform and the user domain should include requirements on threat and friendly unit representations, jungle environment (location, weather, terrain, time of day, etc.), command and control (C2) interfaces, tactics, camouflage, etc.

By examining such things as the use case, scenario, mission and operations, and input data needs, the V&V Agent can realize the context in which the simulation will be used and the results expected by the User.

Simulation domain requirements deal with the implementation of the simulation in both hardware and software. Once the consistency and completeness of the user and problem domain requirements have been established, the simulation domain requirements should be reviewed to determine if the hardware and software environment they define will be adequate to address the user and problem requirements and implement the simulation.

### **Verify Requirements: *Verify Correctness and Completeness***

Individual M&S requirements should be compared with information from authoritative sources<sup>17</sup> to ensure that they are complete and correct. Verification of derived requirements (e.g., requirements created by decomposing other M&S requirements, requirements added to deconflict other requirements) may depend on SME judgment and the use of various analysis techniques. There are also several tools that can assist in this task by providing consistency checking, special grammars, structured English, and similar disciplined approaches; however, their use is usually limited to large, complex simulations because of the start-up costs associated with their use.

### **Verify Requirements: *Verify Requirements Traceability***

[click to review VV&A in New M&S Development](#) page 7

Ensuring that the M&S requirements are appropriately addressed during each phase of the development is an essential V&V task. The primary method for accomplishing this task is requirements tracing. If a requirements tracing database is not provided by the M&S PM or Developer, the V&V Agent should establish one to facilitate this task. Initially, (i.e., during requirements verification), the V&V Agent should ensure that each M&S requirement is appropriately recorded in this database.

In addition, all testable M&S requirements should be linked to one or more tests to ensure that they can be validated against a referent or real-world source (e.g., real-world data, operational test data, results from other similar, accredited simulations, statistics, or SME opinion (face validation)). This linkage is begun during the problem analysis when M&S requirement metrics and acceptability criteria are defined. During this task, the V&V Agent should review the M&S requirements to determine which requirements are indeed testable and to ensure that proper linkage has been established in the requirements tracing database.

### **Verify Requirements: *Verify Inclusion of Acceptability Criteria and Appropriate Metrics***

During the problem analysis,<sup>18</sup> metrics (e.g., measures of performance [MOPs], measures of effectiveness [MOEs])<sup>19</sup> and acceptability criteria are defined for each M&S requirement (see the challenge on [Understanding Acceptability Criteria](#) [p. 9]). However other metrics and acceptability criteria may be needed:

- To address the effectiveness or performance of a major component of the simulation, M&S requirements may need to be grouped together and their associated acceptability criteria linked to measures that address the performance or effectiveness of that component.

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<sup>17</sup> This may involve locating authoritative source documents if explicit references have not been provided by the Developer or User. Potential sources for such information include the program offices for specific systems, information analysis centers, and information repositories, such as the DoD M&S Resource Repository (MSRR).

<sup>18</sup> See special topic on Problem Analysis for additional information.

<sup>19</sup> See the special topic on Measures for additional information.

- The scenario(s) associated with intended use may need to be used to establish metrics and acceptability criteria for measuring the overall simulation's ability to accommodate the scenario(s).

The V&V Agent should use the requirements tracing database discussed in the preceding section, [Verify Requirements Traceability](#), to examine these amalgamations and ensure that they are consistently and accurately grouped and linked.

#### **Verify Requirements: *Evaluate Adequacy of Scenario(s)***

[click to review VV&A in New M&S Development](#) page 7

Each proposed scenario should be assessed to ensure that it is consistent with the needs of the application and contains only elements addressed by the operational and mission objectives and the intended use. If the scenarios will not be finalized until the simulation conceptual model is completed, this task should be postponed until then. However, because scenarios serve to "bound the problem," the lack of one can expand the scope of requirements definition and, subsequently, requirements verification, so the establishment of preliminary scenarios is encouraged.

#### **Verify Requirements: *Document Requirements Verification***

Each requirement verification task should be documented, including objectives assumptions, constraints, methods used, data, and results (as well as all problems, limitations, and recommendations) and the results reported to the M&S PM. The M&S PM reviews and approves all reports prior to distribution to the User, Developer, and Accreditation Agent. The V&V Agent should also meet with the Accreditation Agent to ensure that the information collected and reported meets the needs of the accreditation effort.

#### **Develop V&V Plan**

[click to review VV&A in New M&S Development](#) page 7

For the most part, requirements verification and planning are concurrent: Because both the V&V and development plans depend heavily on the completeness and consistency of the M&S requirements,<sup>20</sup> these requirements should be verified as early as possible to support the planning efforts. Similarly, requirements verification needs to be included in the V&V plan.

#### **Develop the V&V Plan: Planning Information**

The following table lists the information about the simulation for planning that the V&V Agent needs.

Preliminary Planning Information	
Information	Rationale

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<sup>20</sup> See the special topic on Requirements for additional information.

Preliminary Planning Information	
Information	Rationale
<b>Problem to be solved</b>	<ul style="list-style-type: none"> <li>addresses what the simulation is supposed to do or accomplish</li> </ul>
<b>Primary User</b>	<ul style="list-style-type: none"> <li>usually the organization that sponsors the overall program or the V&amp;V effort</li> </ul>
<b>Other users or stakeholders</b>	<ul style="list-style-type: none"> <li>Multiple secondary users may be involved, especially in joint simulation programs</li> </ul>
<b>Fidelity, aggregation, granularity required in the simulation</b>	<ul style="list-style-type: none"> <li>influence the tools and assessment techniques needed to perform the V&amp;V activities</li> </ul>
<b>Complexity and size</b>	<ul style="list-style-type: none"> <li>used in the V&amp;V cost estimate</li> </ul>
<b>Interoperability</b>	<ul style="list-style-type: none"> <li>knowing who else may be involved helps scope the V&amp;V effort</li> <li>can also impact the implementation methodology</li> </ul>
<b>Development paradigm<sup>21</sup></b>	<ul style="list-style-type: none"> <li>determines the overall structure and impacts the scope of the V&amp;V effort</li> </ul>
<b>Proposed development and operating environments</b>	<ul style="list-style-type: none"> <li>helps with selection of appropriate tools, databases, hardware, communications, support systems, and equipment, etc.</li> </ul>
<b>Potential data sources</b>	<ul style="list-style-type: none"> <li>helps determine the extent of the data V&amp;V effort needed<sup>22</sup></li> </ul>

## Develop the V&V Plan: Planning Considerations

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The following considerations have a significant impact on V&V planning and its ultimate execution. They must be known before an adequate plan and cost estimate can be generated because each can impact the selection, level of effort, and scope of the V&V tasks.

- **Acceptability criteria.** The V&V Agent needs to fully understand the acceptability criteria and should work with the M&S PM and Accreditation Agent to determine the types of information and support needed during the V&V effort.
- **Metrics and measures.** The V&V Agent, together with the User, M&S PM, Developer, and Accreditation Agent, should be able to identify and associate the acceptability criteria with the metrics and measures (e.g., MOPs, MOEs)<sup>23</sup> defined for the overall simulation. These measures are typically based on actual situations and real systems<sup>24</sup> that are being simulated. Although some of these measures may be the same as some the acceptability criteria, many of the measures established for the overall simulation are too broad to be

<sup>21</sup> See the special topic on Paradigms for M&S Development for additional information.

<sup>22</sup> See the special topic on Data V&V for New Simulations for additional information.

<sup>23</sup> See the special topic on Measures for additional information.

<sup>24</sup> When future systems are involved, the measures are normally based on system specifications, if they exist, and SME opinion.

considered acceptability criteria. When possible, validation compares simulated performance and effectiveness with real measured performance and effectiveness. How well the two match when the simulation is executed is a strong indication of its validity and fitness for the intended use.

- **Fidelity.** The level of fidelity<sup>25</sup> needed to address a specific application is a highly significant and difficult characteristic to determine. It requires a thorough understanding of the problem being addressed and of how the simulation is to be used. The perpetual question is “how much is enough,” and the answer varies considerably based on any number of factors, such as what characteristics of the entities need to be represented and what behaviors and interactions are expected. The level of fidelity of interacting entities should be roughly equivalent to ensure fair and unbiased interoperability (e.g., a level battlefield). The level of fidelity of the simulation has to be sufficient to adequately and accurately represent the referent (i.e., the representations in the simulation have to be enough like the real systems to satisfy the User’s needs).
- **Resources and schedules.** The scope of the V&V effort cannot exceed the resources allocated. Early involvement by the V&V Agent during requirements verification, participation in the risk assessments,<sup>26</sup> and careful planning should provide sufficient information to adequately determine V&V resource requirements. However, the random nature of unexpected occurrences (e.g., unforeseen events, delays, hardware availability, sudden funding changes, requirements changes, etc.) makes it difficult to adhere totally to plans. Thus, both resource allocations and schedules should be flexible enough to allow priorities to be adjusted throughout the development process at the direction of the M&S PM.
- **Validation data.** Results validation normally involves a comparison of the results of a simulation to a referent. Data describing the referent need to be identified and collected or developed.
- **Availability of tools and equipment.** Sharing development tools and equipment (e.g., data and databases, archives, test beds, communications equipment, support software) can significantly decrease the possibility of problems caused by differences in equipment, thus reducing both cost and risk. However, the V&V Agent should always carefully consider the time and cost required for training and scheduling associated with tools and equipment that are being shared.
- **V&V participants.** As discussed in the challenges section on [Selecting the Right People](#) and [Locating SMEs](#), members of the V&V team should have extensive experience in the V&V field, the systems and technologies represented in the simulation, and the domains encompassed in the application. Selection of additional participants (e.g., SMEs)<sup>27</sup> should be based on their depth of knowledge and experience in the types of activities, the tools available,

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<sup>25</sup> See the special topic on Fidelity for additional information.

<sup>26</sup> See the special topic on Risk and Its Impact on VV&A for additional information.

<sup>27</sup> See the special topic on Subject Matter Experts and VV&A for additional information.

and the scheduling of activities and events. Staffing should be coordinated with the M&S PM.

- **Risk and uncertainty.** Risks and uncertainties associated with building the simulation (i.e., development risks) and with using it in the intended application (i.e., operational risks) and risks associated with specific V&V tasks (e.g., providing incomplete or incorrect results) should be identified as early as possible. Once the objectives and requirements have been defined, a risk assessment<sup>28</sup> should be conducted (normally by the User or Accreditation Agent with support from the M&S PM, Developer, and V&V Agent) to identify the development risks and the operational risks and to help establish priorities for both the development and V&V efforts.

The M&S PM and the V&V Agent should use this information when determining the V&V level of effort and estimating the cost. Risks assessments should be conducted periodically throughout the development effort to ensure the risks and priorities remain current.<sup>29</sup>

- **Leveraging and tailoring.**

**Leveraging** is the technique of using the results of work performed by other participants (e.g., Developer, developmental testers, OTA) to address V&V tasks. For example, if the Developer performs code verification as part of the development effort and it addresses the necessary V&V issues, the V&V Agent should be able to share the evidence and reuse the results without repeating the process. The V&V Agent still has an obligation to review the information and determine its adequacy before accepting it. Such a review typically involves much less time and fewer resources (estimates are normally given as about 10%) than would be expended in a separate code review.

**Tailoring** is the process of selecting and balancing the level of the V&V effort (i.e., the tasks, techniques, and tools selected) with the risks and priorities of the application without becoming excessive in any one area. A tailored approach is one that is reasonable and balanced (neither excessive nor insufficient) and provides adequate evidence for the accreditation assessment to demonstrate the fitness of the simulation for the application. It consists of V&V activities that match the development phases and schedule. The V&V activities are comprised of specific tasks chosen to address the priorities of the application. The allocated funding and resources are sufficient to accomplish them all... Tailoring is closely linked to leveraging because tasks that can be leveraged free funding and resources for use on other tasks. For additional information see [Appendix F](#):

- **Data.** As shown in the Data V&V for New M&S diagram below, the V&V process and the data V&V process are complementary. The level of effort involved in data V&V activities varies from very low, for data prepared and

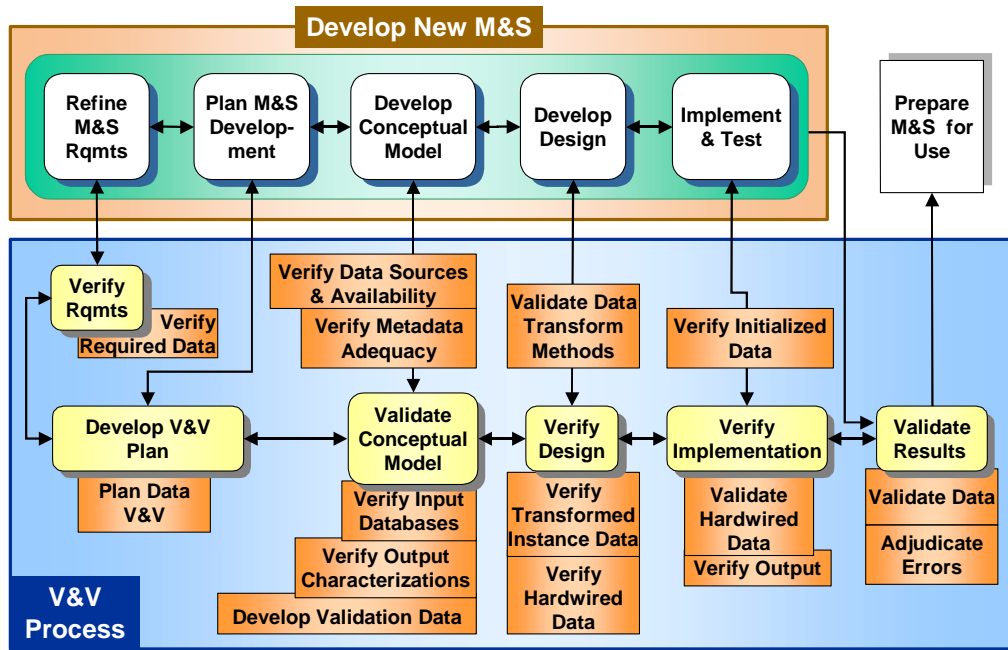
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<sup>28</sup> See the special topic on Risk and Its Impact on VV&A for additional information.

<sup>29</sup> See the core document on the M&S PM Role in the VV&A of New Simulations for additional information on development risk and uncertainty,



provided by authoritative sources (who also provide extensive information regarding data quality<sup>30</sup>), to relatively high, for data generated by the M&S Developer or User from whatever sources are available (e.g., live tests, experiments, statistics, SME opinions). In the latter case, data quality, appropriateness, accuracy, reasonability, etc. need to be checked much more extensively.<sup>31</sup>



**Data V&V for New M&S**

- **Documenting and reporting V&V activities.** The documentation of each V&V activity should include the objectives, assumptions, constraints, methods employed, data, tools, techniques, artifacts produced, and the results of the assessment and review. The M&S PM should review and approve all reports prior to distribution. However, as major tasks are completed, the V&V Agent should brief the M&S PM, Developer and Accreditation Agent on the findings as appropriate. The V&V Agent should also meet frequently with the Accreditation Agent to ensure that the information being collected and reported meets the needs of the accreditation effort.

### **Develop the V&V Plan: Creating the V&V Plan**

[click to review VV&A in New M&S Development](#) page 7

The V&V plan is a document that addresses both phase-dependent and phase-independent V&V activities required to carry out the all the objectives (and contractual agreements) of the V&V project. It depends heavily on the contributions of the

<sup>30</sup> See the RPG templates on Data Quality for additional information.

<sup>31</sup> See the special topic on Data V&V for New Simulations for additional information.

Developer, M&S PM, Accreditation Agent, and others. The quality and comprehensiveness of the plan have a major impact on the effectiveness of the V&V effort in assessing the fitness of the simulation and providing information to support the accreditation assessment.

The following steps complete the V&V planning function:

- determine which V&V activities are required
- state how each activity will be accomplished (i.e., what tasks are involved) and what M&S requirements and objectives each will address; include any plans to leverage off work performed by others
- determine what techniques will be used
- assign responsibilities for each task
- determine who is responsible for scheduling and resources for each task if it is someone other than the V&V Agent (e.g., the Developer or M&S PM when tasks are leveraged or resources are shared )
- identify other required resources(e.g., tools, SMEs, additional support personnel, additional hardware or software, significant travel)
- establish points of contact (POCs) with all participants (e.g., M&S PM, User, Accreditation Agent, Developer, testers)

The V&V plan should be handled as a living document; iteration is to be expected. The planning steps should be repeated as required until the M&S requirements and development plans are stable and until the M&S PM and V&V Agent agree that the proposed plan can satisfy the needs of the other participants and can provide the necessary information for accreditation. When requirements are changed, added or eliminated or when the schedule changes or the scope of the development effort is redefined, the V&V plan should be adjusted as well. Thus, some amount of iteration can be expected.<sup>32</sup> Additional information on planning is available in [Appendix B](#).

### ***Validate Conceptual Model***

[click to review VV&A in New M&S Development](#) page 7

A conceptual model is a collection of information that describes a Developer's concept about the simulation and its constituent parts. This information includes descriptions of entities, objects, algorithms, relationships (i.e., architecture), and data as well as assumptions and limitations. The conceptual model<sup>33</sup> serves as a bridge between the Developer and the User, demonstrating the Developer's understanding of the intended application. It also

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<sup>32</sup> See the RPG VV&A Planning and Report Templates for additional information.

<sup>33</sup> See the special topic on Conceptual Model Development and Validation for additional information.



- connects the design to the requirements, by providing a comprehensive description of the architecture, algorithms, behaviors, interactions, and capabilities to be addressed in the design specification
- supports the transition from requirements to design by serving as the framework where the M&S requirements are converted into the necessary capabilities needed by simulation
- includes descriptions that correctly describe missions, operations, behaviors, and performance capabilities that agree with the mission and operational requirements defined by the scenario
- includes descriptions that adequately characterize the real-world systems, entities, interactions, and environments specified in the intended use
- serves as a referent for results validation by virtue of its ties to real-world systems, entities, missions, and operations. In essence, the validated conceptual model becomes or at least bounds the referent for the simulation because it presents an adequate representation of the performances, behaviors, interactions, and fidelity needed to meet the intended use. The referent is essential in determining how to test and validate the simulation, and it can provide guidance on how to reuse it in the future
- presents a thorough functional-level description and architectural model of the M&S that is capable of supporting the design process and future reuse

Conceptual model validation is done to ensure that all participants, especially the Accreditation Agent and Developer, have a clear and accurate understanding of the Developer's vision of intended use and proposed capabilities of the simulation. Conceptual model validation consists of a series of reviews and assessments by the V&V Agent and appropriate SMEs to determine if the various parts of the conceptual model are adequately defined and represented.

### Conceptual Model Validation Tasks

[click to review VV&A in New M&S Development](#) page 7

Conceptual model validation involves different tasks, such as those listed below. The specific tasks involved and the level of effort associated with each should be tailored to meet the needs of the current application.

#### **Validate Conceptual Model: *Verify Requirements Mapping***

The combination of user domain and problem domain requirements should be traced into the conceptual model to ensure that both are adequately and accurately represented. These requirements collectively determine the operational aspects of the simulation; that is, what the simulation is supposed to do and how well it should be done (i.e., at what level of fidelity and realism). Additional user and problem domain requirements may be derived during the creation of the conceptual model as requirements are decomposed and aggregated to ensure appropriate levels of fidelity

and realism, and these requirements need to be reviewed as well to ensure that they trace appropriately to the originating requirements and do not introduce inconsistencies.

The simulation domain requirements should also be traced, since they directly affect the initial design of the new M&S by defining functionality, algorithms, and capabilities that the M&S must have to support the operational requirements. Additional simulation domain requirements that are derived as the details are expanded during creation of the conceptual model also need to be traced to the originating requirements and examined for consistency.

**Validate Conceptual Model: *Evaluate Basic Framework and Architecture***

[click to review VV&A in New M&S Development](#) page 7

The behaviors, relationships, interactions, and algorithms associated with systems and other entities should be examined and validated with reference to the emerging simulation architecture being defined and depicted in the conceptual model. In a large, complex simulation, this validation can be done piecemeal in the beginning as long as the manner in which entities behave, interact, and interface with the synthetic environment is included to ensure that appropriate representations of the real world are incorporated in the conceptual model.

**Validate Conceptual Model: *Evaluate Instance Data Requirements***

[click to review Data V&V for New M&S](#) page 21

Data needs<sup>34</sup> identified by the Developer and User should be reviewed to ensure that they are appropriate for the identified use (e.g., a data requirement for night vision data is not needed for a daytime scenario).

**Validate Conceptual Model: *Verify Data Sources and Availability***

Once the conceptual model begins to mature, it is usually possible for the User and M&S PM to begin investigating the availability of candidate input data. Often the necessary databases can be acquired from authoritative sources. However, when authoritative data sources are not available, additional data V&V tasks will need to be performed to ensure the appropriateness of the data. Thus, when potential data sources are identified, they should be examined to ensure that they can provide data that are appropriate for the intended use.<sup>35</sup> For example, the authoritative data source for tank data for an Army training simulation will likely be different from the authoritative data source for tank data for an Air Force air-ground combat simulation.

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<sup>34</sup> The types of data required by any simulation are extremely varied and their identification may occur during different stages of the development effort. Although many data requirements are identified during conceptual model development, others may not be defined until the detailed design has been established. Therefore, the selection, preparation and evaluation of different data types can be expected to occur throughout the early phases of the development process. For the purposes of this document, data-related activities are discussed at the earliest or most typical time they may be expected to occur.

<sup>35</sup> See the special topic on Data V&V for New Simulations for additional information.

### **Validate Conceptual Model: *Verify Databases and Metadata***

[click to review Data V&V for New M&S](#) page 21

Once identified, input databases and data sets should be reviewed to ensure that they contain the specified data for the application. The metadata associated with the input data should also be reviewed to ensure that they provide sufficient detail regarding the quality of the data for effective use.<sup>36</sup>

Data<sup>37</sup> should be ready for use in the simulation well before they are needed, so data V&V activities should be scheduled whenever possible. Input data V&V tasks are repeated for every different data set involved in the simulation. Because different data sets are selected and obtained at different times, and because the number of different data sets involved in any simulation is extensive, this task may continue into the next phase. The M&S PM will determine when enough of the data sets have been examined and it is prudent to begin the next phase of development.

### **Validate Conceptual Model: *Evaluate Fidelity of Planned Representations***

[click to review VV&A in New M&S Development](#) page 7

**Fidelity**<sup>38</sup> describes the degree to which the state and behavior of the simulation representations reflect the real-world objects, features, etc. being represented. The V&V effort should examine the fidelity characteristics of the simulation to ensure that they are sufficient for the intended application (e.g., the fidelity of a tank model required for detection by an IR sensor is far different from the fidelity required for visual detection, since the IR detector operates from the heat stored in the tank and not its appearance).

### **Validate Conceptual Model: *Review Acceptability Criteria***

The acceptability criteria should be reviewed to ensure that the original assumptions governing them have not changed and that they

- remain appropriate and sufficient for the requirements and their associated metrics
- are complete and traceable to the requirements
- are reasonable considering how the simulation is being conceptualized
- are fully addressed within the scope of the V&V effort

### **Validate Conceptual Model: *Evaluate Scenario(s) and Timelines***

[click to review VV&A in New M&S Development](#) page 7

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<sup>36</sup> See the Data Quality Templates for additional information.

<sup>37</sup> See the reference document on M&S Data Concepts and Terms for additional information.

<sup>38</sup> See the special topic on Fidelity for additional information.

The scenario identified in the conceptual model should be assessed to ensure that it adequately address the requirements and does not involve elements beyond the scope of the intended use (e.g., a scenario set in Panama should be eliminated when the purpose of the application is to evaluate the detectability of desert camouflage equipment).

### **Validate Conceptual Model: *Document Conceptual Validation***

Each conceptual model validation task should be documented, including its objectives, assumptions, constraints, methods used, data, and results (e.g., problems, limitations, recommendations), and the results should be reported to the M&S PM. The M&S PM reviews and approves all reports before they are distributed to the Developer, Accreditation Agent, and User. The V&V Agent should also meet with the Accreditation Agent to ensure that the information collected and reported meets the needs of the accreditation effort.<sup>39</sup>

### **Surrogate Conceptual Models**

In some development efforts, the conceptual model takes on different forms as a result of the development paradigm selected, the resource and time constraints, and the background of those involved.

- In object-oriented development, use cases have served as the mechanism to move from requirements to design, bypassing a more formal conceptual model [Jacobson, 1992].
- Another surrogate conceptual model can be made by starting with one or more of the user manuals and adding attachments containing the traditional conceptual model elements.

When a surrogate conceptual model is used, the Developer should provide details on its structure to the V&V Agent to assist in validation. Regardless of what form the conceptual model takes, the information it contains should be sufficient to support follow-on development phases and VV&A activities.

If the conceptual model is not identified as a formal development product the V&V Agent may be asked by the M&S PM to assemble all the available information products (e.g., descriptive information, diagrams, algorithms, behaviors, performance data, scenarios, constraints, representations, limitations, interactions, operational and mission descriptions) into a surrogate conceptual model to serve as the basis for evaluation. The Developer should be prepared to work with the V&V Agent to identify the various products that should be included. The M&S PM is responsible for deciding if the surrogate provides sufficient information for the V&V and accreditation efforts or if the Developer should enhance the conceptual model.

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<sup>39</sup> See the special topic on Conceptual Model Development and Validation for more information.

Validation of a surrogate conceptual model is complex because it entails validating each component separately and then validating the integrated surrogate. However, validation is essential because it provides evidence that the Developer's vision is credible, sufficient, and complete. When dealing with a surrogate conceptual model, the V&V Agent may need additional time and assistance developing a validation plan as well as additional assistance identifying, collecting, and explaining the various pieces of information involved.

## Verify Design

[click to review VV&A in New M&S Development](#) page 7

During the design phase, the Developer takes the capabilities derived from the requirements, architectural representations, algorithms, behaviors, interactions, data requirements, constraints, and limitations defined and described in the conceptual model and translates them into a design specification that will support their implementation in software and hardware. For large, complex simulations this can include custom hardware, such as a flight trainer, for which separate hardware specifications are required.

The purpose of design verification is to ensure that all the features, functions, behaviors, algorithms, and interactions are correctly and completely included in the design representations and documentation. Design verification relies heavily on the products coming from the design process, including those listed in the following table:

Design Products and Artifacts
• Design documentation
• Design representations
• Algorithms and data specified
• Diagrams and drawings
• Interface control drawings
• Database formats
• Task results
• Peer review reports
• Design review reports
• Walk-through reports

For the efficient and economical completion of this activity, these products should be comprehensive, accurate, and timely.

## Design Verification Tasks

[click to review VV&A in New M&S Development](#) page 7

Design verification involves a number of different tasks, such as those listed below. The specific tasks involved and the level of effort associated with each should be tailored to meet the needs of the current application. Because the design is usually

developed in stages (e.g., preliminary design, detailed design), verification tasks should be tailored to and coordinated with each stage of the design. Only the tasks that are essential to establish the necessary level of credibility and to support accreditation should be included. Verification tasks performed adequately by the Developer should be leveraged to save resources.

### **Verify Design: *Verify Requirements Mapping***

A significant task in any V&V effort is to ensure that all requirements are correctly traced into the design. A comprehensive conceptual model reduces the scope of effort needed for this task by serving as the bridge between requirements and design. The M&S requirements were first verified and mapped into the conceptual model (see [Verify Requirements Mapping](#) in the previous activity). This task continues the mapping process by tracing them from the conceptual model into the design to ensure that none were inadvertently omitted or corrupted. A tracing tool or database is highly recommended for this task.

### **Verify Design: *Verify Design Artifacts***

[click to review VV&A in New M&S Development](#) page 7

The V&V Agent should review and assess the completeness and consistency of the design artifacts and provide timely feedback to the Developer. The approach to this task varies based on the development paradigm<sup>40</sup> being followed, the development method (e.g., object oriented, structured, knowledge based), and whether or not the Developer uses computer-aided software engineering (CASE) tools.

### **Verify Design: *Assess Algorithms***

Key algorithms should be examined for their accuracy and their fitness for the application (e.g., perform at an appropriate level of fidelity and accuracy; provide useful, correct output, etc.) and for their suitability for the input data involved.

### **Verify Design: *Verify Interfaces***

[click to review VV&A in New M&S Development](#) page 7

The specifications of the internal and external interfaces identified in the design should be verified to ensure that information can be passed as needed for the intended use (i.e., data are sent to the appropriate receptors in appropriate formats at appropriate times). If the simulation is being developed with the option of becoming a federate in a federation, the external interface design should be checked for compatibility with distributed simulation standards, such as the high level architecture (HLA).

### **Verify Design: *Assess Timing and Sizing***

Timing and sizing requirements for different behaviors and interactions (e.g., the amount of time needed to complete a critical software task or process; the amount of

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<sup>40</sup> See the special topic on Paradigms for M&S Development for additional information.



memory needed to process, transfer, or store data) should be checked to ensure that the execution of the simulation is not impeded or distorted.

### **Verify Design: *Validate Data Transformation Methods***

[click to review Data V&V for New M&S page 21](#)

The techniques used to prepare data for use in the simulation (i.e., in the algorithms) should be examined to ensure that data accuracy, completeness, and integrity are maintained. This is especially important when data need to be extensively manipulated in order to be usable. Input data are always transformed in some way for use in a simulation, if only by being transferred from one data set to another. Ideally, the data sets selected for use are very close to what is needed, and only minor conversions are necessary (e.g., miles to kilometers; probabilities of acquisition, shot and kill to a single shot kill probability (SSKP)); however, in many cases data need extensive transformations to be used by the algorithms in the simulation. The responsibility for ensuring the validity of the transformation methods is often shared between the data provider (authoritative source) and the Developer and supported by the V&V Agent.<sup>41</sup>

### **Verify Design: *Verify Transformed Data***

[click to review Data V&V for New M&S page 21](#)

Data that have been transformed<sup>42</sup> and prepared for use in the simulation should be verified to ensure that they correspond appropriately to the original intent<sup>43</sup> and are in an appropriate form for use in the simulation. This task involves mapping the input data to the source data by checking for matches between the source and input definitions and structures, searching for translation and format errors, scalar notation and conversion correctness, missing fields, corrupted names and values, range checking, and similar quality checks (see [Verify Databases and Metadata](#) in previous activity). This task should be conducted in concert with the validation of the transformation methods.<sup>44</sup>

### **Verify Design: *Verify Test Plans***

[click to review VV&A in New M&S Development page 7](#)

The V&V Agent should review and assess the developmental test plans and work with the Developer to include validation test issues where possible. It is usually more cost-effective to combine tests than to prepare and run separate, independent validation tests, although this is a possible alternative. Balancing developmental and V&V test needs and objectives is the responsibility of the M&S PM, who also has final authority

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<sup>41</sup> See the special topic on Data V&V for New Simulation for additional information.

<sup>42</sup> Input data tasks are repeated for every different data set involved in the simulation. Because different data sets are selected and obtained at different times, and because the number of different data sets involved in any simulation is extensive, this task may begin before this phase and may continue into the next phase. The M&S PM will determine when enough of the data sets have been examined and it is prudent to begin the next phase of development.

<sup>43</sup> Because input data for a simulation often result from the combination of data (e.g., SSKP) there may be no one-to-one correspondence between the input data and the source data. When this is the case, the assessment must focus on the purpose of the source data, validity of the transformation algorithm, and the reasonableness of the resulting input data.

<sup>44</sup> See the special topic on Data V&V for New Simulation for additional information.

on who will be responsible for which tests. Final agreements on test plans, activities, and areas of responsibility should be specified in writing. How testing is to be performed varies greatly with the type of simulation, its intended use, and the availability of facilities and resources. Test plans should address all of the requirements in terms of their associated metrics and acceptability criteria specified for adequate validation of the simulation.

### **Verify Design: *Document Activities***

Documentation of each design verification task should include the task's objectives, assumptions, constraints, methods, and results (e.g., problems, limitations, recommendations). The results of the design verification activity should be reported to the M&S PM, who reviews and approves all V&V reports prior to distribution. The V&V Agent should also meet with the Accreditation Agent to ensure that the information collected and reported meets the needs of the accreditation effort. Problems or limitations identified but not addressed by the Developer should be documented, as they may affect the accreditation assessment process.

### **Verify Implementation**

[click to review VV&A in New M&S Development](#) page 7

During the implementation phase, the M&S design is realized in hardware and software. Both types of components are constructed, tested, and integrated, and the actual data and databases are installed and tested. When custom hardware is involved, the scope of the V&V effort can grow significantly to include the review and assessment of fabrication and integration of the hardware. The Developer may conduct or assist with the following tasks, or the V&V Agent may be tasked to perform them independently. When the Developer conducts a verification task, the V&V Agent should leverage it.

### **Implementation Verification Tasks**

Implementation verification involves a number of different tasks, such as those listed below. The specific tasks involved and the level of effort associated with each should be tailored to meet the needs of the current application and the specific needs of the other participants in the program.

### **Verify Implementation: *Verify Requirements Mapping***

[click to review VV&A in New M&S Development](#) page 7

This task continues the mapping process by tracing the requirements from the design to the code and hardware to ensure that they are being addressed correctly and completely (see [Verify Requirements Mapping](#) in the previous activity).

### **Verify Implementation: *Verify Code***



Code should be run on static and dynamic analyzers<sup>45</sup> to identify latent errors and to ensure accurate execution where possible. Dynamic analyzers can also be used to exercise all of the paths in the software to ensure full execution and test coverage. When coding standards are imposed in the development contract, this step can also verify that they are being followed.

**Verify Implementation: *Verify Hardware Configuration and Implementation***

[click to review VV&A in New M&S Development](#) page 7

Interfaces between components should be checked to ensure accurate implementation. When unique hardware is involved, this task can expand to verify the hardware implementation (e.g., design specifications, drawings, parts lists). The scope of this work is defined by the V&V Agent and the M&S PM.

**Verify Implementation: *Verify Software/Hardware Mapping***

Software allocations and assignments to hardware components should be checked for correctness.

**Verify Implementation: *Verify Hardware***

When special hardware is required, a significant amount of verification may be required. For example, weapon system physical models, cockpit mockups, visualization systems employing optics, simulators that provide motion, and simulations that support safety-critical systems may require hardware verification beyond verifying the configuration and software/hardware mapping.

**Verify Implementation: *Verify Initialized Data***

[click to review Data V&V for New M&S](#) page 21

Initialized data sets should be checked to ensure that data have maintained the accuracy and integrity required by the application. This task continues the task of mapping the input data by comparing the initialized data values to the values in the input databases to verify that the proper data are being initialized and the proper transformations (if any) have taken place (see [Verify Transformed Data](#) in previous activity).

**Verify Implementation: *Verify Tests***

[click to review VV&A in New M&S Development](#) page 7

Test plans and procedures (e.g., developmental tests (DTs); operational tests (OTs)) should be reviewed to determine if they can provide information needed for the V&V effort. When possible, testing activities should be coordinated (e.g., scenarios, tests suites, data, events, results) to minimize costs and increase efficiency. During

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<sup>45</sup> A code analysis tool can be very cost-effective for identifying and correcting latent errors. The more comprehensive of these tools provides both static and dynamic analysis of the software. The static portion deals with standards enforcement and violations of good coding practices; the dynamic portion executes code on a user-selected basis.

combined testing, the V&V Agent should help conduct and analyze test results, especially those that address V&V issues and acceptability criteria.

### **Verify Implementation: *Document Activities***

Each code verification task should be documented, including objectives, assumptions, constraints, methodology, data, and results (e.g., problems, limitations, recommendations), and the results reported to the M&S PM. The M&S PM reviews and approves all reports prior to their distribution to the Accreditation Agent and User. The V&V Agent should also meet with the Accreditation Agent to ensure that the information collected and reported meets the needs of the accreditation effort. Problems or limitations identified but not addressed by the Developer should be documented, as they may affect the accreditation assessment process.

### **Implementation Verification Tools and Equipment**

Code analysis tools<sup>46</sup> can be quite cost-effective for identifying and correcting latent errors. Higher-end code analysis tools provide both static and dynamic analysis of the software:

- **static analysis** focuses mostly on standards enforcement, identification of flawed logic, coding errors, and violations of good coding practices
- **dynamic analysis** executes code on a tool-bearing host and can be used either to focus selectively or to execute 100% of all paths in the software

According to studies performed by Dr. E. F. Miller, conscientious use of code analysis tools should detect 75% to 95% of the common coding errors. Regardless of who analyzes the code (e.g., DT, OT, Developer, Test & Evaluation (T&E) Agent, V&V Agent), the results should be documented as part of the V&V effort and included in the implementation verification report [Miller, 1980].

### **Validate Results**

[click to review VV&A in New M&S Development](#) page 7

Results validation is conducted to determine

- the extent to which the simulation addresses the M&S requirements
- how realistic the simulation outputs are under conditions determined by the application
- how well the simulation fits the intended use

Validation<sup>47</sup> should be performed through comprehensive iterative testing and assessment of all the functionality and representations to ensure that everything is

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<sup>46</sup> See the reference document on V&V Tools for additional information.

working. The specific tasks involved are highly dependent upon the type of simulation and its intended use. As a general rule, discrete pieces or components of the simulation are validated separately, in priority order, to determine if they perform their functions adequately. They are then integrated incrementally and tested in combination until the entire system is completely tested as a single item.

**Examples:**

- A terrain database and its resulting synthetic environment can be validated before as well as after battlefield entities and objects have been added.
- Special hardware required to support the simulation should be inspected and validated as far as possible before being integrated with the rest of the simulation.
- Communication networks should be tested and validated before being used in testing the overall simulation.

## **Validation Tools**

Results validation should be supported by appropriate analysis tools.<sup>48</sup> It is often beneficial for the V&V effort to have its own limited testing capabilities and tool suite to support results validation. However, under typical schedule and resource restrictions it is not normally cost-effective to assemble comprehensive independent V&V test facilities. Such decisions are normally made by the M&S PM and are based on economics, program needs, risks, and the amount of validation testing that can be leveraged from all sources. See [Appendix E](#) for additional information.

Who performs specific validation testing tasks should be determined by the V&V Agent and M&S PM in consultation with the Developer. Validation testing can frequently be performed in conjunction with other testing efforts; however, some level of independent validation testing should be encouraged as long as it does not present an economic burden. When test facilities and resources have limited availability, the M&S PM should encourage the Developer and V&V Agent to work together where possible.

## **Validation Data**

Results validation normally involves comparison of the results of a simulation to the referent. As stated in the section on [conceptual model validation](#), the conceptual model bounds the validation activities by serving as the referent upon which the validation tests are based. Data describing the referent (i.e., validation data) should be identified, collected or developed, and validated. Real-world empirical data are preferable (e.g., physical measurements, test range results, historical records). However, when real-world data are not available, appropriate test scenarios should be developed and SMEs asked to provide reasonable, expected outcomes for the scenarios or use cases to be

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<sup>47</sup> See special topic on Validation for additional information.

<sup>48</sup> See the reference document on V&V Tools for additional information.

executed in the simulation [Rothenberg, 1997]. These validation data, both empirical and expected outcome, should be carefully evaluated to ensure they are appropriate to use. Attempts to validate a simulation in the absence of appropriate, valid test data or measured phenomena can be very uncertain, and can lead to incorrect or misleading assumptions about the validity of the simulation.

**Examples:**

- The original simulations of particle beam weapons relied on a number of assumptions about the physics involved that were based on the best expert opinions of the time. However, when hardware prototypes were finally built and tested in the atmosphere these assumptions were later found to be incorrect.
- The performance capabilities and behaviors of a fielded Army tank are so well known that the tank “model” can be thoroughly validated for a wide range of applications from real-world test data.

## Results Validation Strategy

A standard validation strategy is to focus on the acceptability criteria, critical functions, and any areas in which additional testing will mitigate risk and provide evidence regarding the validity and credibility of the simulation in priority order. When defining the validation tests, the V&V Agent should focus on the following three issues:

- ensure that test coverage is correctly focused to support accreditation
- mitigate as much operational risk as possible
- ensure that the M&S is fit for the intended use<sup>49</sup>

The validation process should include explicit acceptability criteria for judging the degree of correlation between the simulation outputs to the referent (i.e., real-world referent data, results from operational tests and evaluations, results from other accredited M&S, statistical techniques, or SME opinion). Acceptability is all too often determined only by the person comparing the results and is seldom documented. A number of different techniques are available (e.g., engineering judgment, face validation, sensitivity analysis, statistical methods) and their use in validation varies a great deal based on how deterministic and predictable the M&S outputs happen to be.<sup>50</sup>

## Results Validation Tasks

[click to review VV&A in New M&S Development](#) page 7

Some of the specific tasks performed during results validation include the following:

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<sup>49</sup> See the reference document on A Practitioner's Perspective on Simulation Validation for additional information.

<sup>50</sup> See the reference document on V&V Techniques for additional information.

### **Validate Results: *Map Tests to Requirements***

This task confirms that every testable requirement cited in the conceptual model is mapped to one or more tests and none is left untested. As discussed in [Verify Test Plans](#), the suite of tests (e.g., DT, OT, validation testing) should be traceable to the M&S requirements and their associated metrics and acceptability criteria. This process is supported by the incremental tracing of requirements through the conceptual model, design, and implementation and into the tests.

### **Validate Results: *Validate Required Behaviors, Representations, Algorithms, and Models***

This activity examines the extent to which different aspects of the simulation can provide appropriate (human) responses when driven by valid instance data and exercised in the context of the scenario and intended application.<sup>51</sup>

### **Validate Results: *Validate Data***

[click to review Data V&V for New M&S page 21](#)

This task assesses the impact of the input data on the performance of individual algorithms and components and on the integrated simulation. Because the data and the M&S implementation are inextricably intertwined (i.e., if one is not valid, then the validity of the other cannot be determined), the validation of both should be conducted concurrently, where possible. In some respects, this part of results validation can be viewed as the calibration of data and model.

Although all data involved in testing are subject to validation, the data that most directly impact high-risk areas of the simulation should be assessed first. Critical path analysis is often used to determine the order of the validation tasks to ensure that dependencies are being correctly managed. Data validation can be conducted incrementally.

#### **Example:**

The terrain database for a battle simulation can be validated before battle entities and objects are added. Sensitivity excursions can also be run to test the boundary conditions of key data elements and to assess the tolerance of simulation execution and output to variations in data values.

The methods used to test data validity vary greatly, depending in part on the type of data involved. The data needed to execute a simulation vary from the large, complex databases such as terrain, atmosphere, sea, weather effects, etc. to smaller databases of more specific things such as radio frequency (RF) and infrared (IR) signatures, characteristics of an artillery shell in flight, or the speed or motion of an object. Validation of the large, complex databases may require significant resources, while more specific data may best be validated in the context of tests in which the data are

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<sup>51</sup> See the special topic on Human Behavior Representation Validation for additional information.

being used. Fortunately, the larger databases often come from authoritative sources with a V&V history, although confirmation is required to demonstrate their suitability in the current context.<sup>52</sup>

[click to review VV&A in New M&S Development](#) page 7

### **Validate Results: *Adjudicate errors***

Anomalous behavior (inconsistencies, errors, and discrepancies between simulation responses and the referent) should be examined to determine the probable cause. Anomalous behavior can result from many sources: hardware, code, data, or occasionally a combination of the three. Identifying the cause is the first step in resolving the problem.

Anomalous outputs can often be traced back through the code and may require further tracking into the design or even to a requirement that cannot be met consistently. Other anomalous behavior and borderline performance should be assessed using engineering judgment and/or further test runs to attempt to isolate the cause and determine if the problem is real or not. Sensitivity analysis, boundary testing, and Monte Carlo runs can sometimes assist in this process<sup>53</sup>. Results of all such investigations, testing, and assessments should be documented and included in the results validation report.

### **Validate Results: *Document Activities***

[click to review VV&A in New M&S Development](#) page 7

The V&V Agent should collect and record all information associated with each results validation task (regardless of who performs it), including the objectives, assumptions, constraints, methodology, data, and results (e.g., problems, limitations, recommendations). Results should be reported to the M&S PM. The M&S PM should review and approve all reports prior to their distribution (to Accreditation Agent, User, Developer). The V&V Agent should also meet with the Accreditation Agent to ensure that the information collected and reported meets the needs of the accreditation assessment. Problems or limitations identified but not addressed by the Developer should be documented, as they may affect the accreditation assessment process.

### **Validate Results: *Prepare V&V Report***

Once results validation has been completed and the results accepted by the M&S PM, the V&V Agent prepares the formal V&V report and submits it to the M&S PM for review and subsequent distribution. This report should include

- interim reports from each V&V activity
- a summary of the accomplishments, findings, conclusions, and recommendations of the overall V&V effort

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<sup>52</sup> See the special topic on Data V&V for New Simulations for additional information.

<sup>53</sup> See the reference document on V&V Techniques for additional information.

- a list of all the evidence, data, documentation, assessments and reports associated with the V&V effort, including information leveraged from other parts of the program

Once this report has been approved by the M&S PM, it should be distributed to the Accreditation Agent for use in the accreditation assessment. The V&V Agent should also meet with the Accreditation Agent to ensure the materials provided throughout the V&V effort have satisfied the information needs of the accreditation assessment.

## ***Other Considerations***

### **V&V Management**

Although the V&V effort is monitored by the M&S PM who is responsible for overseeing and managing the overall simulation development program (including the V&V effort), the V&V Agent is in charge of implementing the V&V plan. In this capacity, the V&V Agent has several management responsibilities, including

- keeping the V&V effort focused on essential technical activities
- selecting appropriate and available tools, methods, and techniques and changing them to match the program changes when required
- ensuring that the necessary resources are available when needed
- locating appropriate personnel to participate in the V&V effort and providing adequate training when needed
- keeping current with the Developer's configuration management system and products
- providing sufficient evidence to adequately support the accreditation decision within available resources
- meeting the goals and objectives specified in the V&V plan

Most successful V&V efforts use both informal and formal lines of communication and reporting to support these objectives, such as daily staff meetings, ad hoc problem solving sessions, weekly status meetings with the M&S PM, and frequent discussions with the Developer and the Accreditation Agent. When requested by the M&S PM, the V&V Agent also meets with the User.

### **Configuration Management**

Configuration management of a new development should include a process for standardization and control of development products and their associated archives. The Developer's configuration control process, often based on a developer configuration control board (DCCB) or similar oversight group, should provide a process for reviewing changes to the simulation during development. Before any changes are



made, they should be documented (e.g., using Internal Change Request forms) and submitted for approval by the oversight group. Both the V&V Agent and Accreditation Agent should participate in this oversight group.

The V&V Agent should use the Developer's configuration management system to the maximum extent possible. Since most of these systems are now on-line, the V&V Agent should have a user account that will enable access to all records on a read-only basis. In addition, the V&V Agent should also have write privileges for entering problem reports and correction requests (or the equivalent).

## V&V Tracking, Oversight, and Reporting

Tracking is the process of evaluating the actual performance of the V&V effort with respect to the planned V&V effort and comparing the costs accrued against the budget on a periodic basis. At the beginning of the V&V effort, the V&V Agent and M&S PM should determine the metric data to be collected, the techniques to be used in its interpretation, and the reporting of formats and schedules. Status reports to the M&S PM should be produced regularly (typically on a monthly basis for new M&S developments).

## Support Systems and Infrastructure

To function efficiently, V&V efforts need to establish a system of support mechanisms. To be cost-effective, these mechanisms need to be scaled to the size and duration of the effort. It is considered good practice to provide the minimum infrastructure and support systems that function satisfactorily for the development effort in question.

- **Support Tools.**<sup>54</sup> The V&V effort often requires tool-bearing host computers and special software packages and tools, some of which may also be used by the Developer. Usually, these products can be obtained from the Developer or through the M&S PM to support the V&V effort or by individual arrangements with tool vendors. The M&S PM may want to purchase tools for both the Developer and V&V Agent at the same time to ensure compatibility. Occasionally, however, the Developer (owner) may want to retain possession of these items and will have to provide support to the V&V Agent. In other cases, V&V tools can be used to perform code analysis, requirements tracing, data reduction and assessment, and any number of analytical tasks. For additional details on tools, see [Appendix G](#).
- **Documentation Library.** To work efficiently, the V&V Agent should either assemble a documentation library or have free access to the Developer's library. This library typically contains copies of all plans, reports, data, deliverables, and working papers pertinent to this M&S. It is also likely to include reference books, papers, materials, and source documents pertaining to the systems being modeled, as well as other inputs used in planning the intended use.

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<sup>54</sup> See the reference document on V&V Tools for additional information.

Libraries of this type are generally a combination of hard-copy documents and electronically stored media. If the M&S PM specifies all development deliverables be prepared in electronic media, it is a very simple process for the V&V Agent to be granted access.

- **Software Library.** The software library contains all of the official releases of the software from the M&S Developer and the data and databases used for input. It should also contain the test data from every test that the V&V Agent decides to assess, whether run by the Developer or the V&V Agent, and regardless of purpose. The object of maintaining this information is to be able to recall and, when necessary, recreate tests at will and to quickly associate their software release, data, test cases, and procedures. It is preferable, though not essential, that the V&V Agent use the same code management system as the Developer; the systems do need to be compatible.
- **Security.** Security concerns both the physical security provided by the facility and the safe handling and storage of classified material, which should be done in accordance with the DD Form 254 for the M&S project.

## **V&V Agent's Relationship with Other Roles**

### ***V&V Agent's Relationship with the User***

The V&V Agent's major concern is to satisfy the User by identifying potential problems and by providing evidence of the simulation's fitness for the intended use. In most cases, this relationship is achieved indirectly through cooperative relationships with the Accreditation Agent and the M&S PM. However, the V&V Agent does look to the User to provide SMEs for various V&V activities (e.g., to ensure that the behaviors, representations, and performance of the required elements are within acceptable limits). The User should recognize that the V&V effort is the primary means for determining that the simulation will be able to satisfy the intended use. The User should be encouraged to participate in different V&V activities to stay abreast of the evolving status of the product (e.g., requirements verification, conceptual model validation, design verification, and results validation).

### ***V&V Agent's Relationship with the M&S Program Manager***

The M&S PM normally hires the V&V Agent and allocates resources to the V&V program. The M&S PM is the one to whom the V&V Agent reports, and the one who oversees the V&V effort. The V&V Agent is responsible for producing the detailed V&V plan and conducting the V&V effort. Although the V&V Agent normally works directly with both the Developer and the Accreditation Agent, all activities should be coordinated and all findings reported through the M&S PM. At times, the M&S PM will have to make decisions on resource utilization that will affect both the development and the V&V efforts.

The V&V Agent should coordinate with both the M&S PM and the Developer during the planning period to schedule V&V tasks appropriately and to determine availability of the necessary resources. The M&S PM should help the V&V Agent integrate plans and coordinate activities with the Developer to ensure that development products and information (e.g., input data, M&S requirements, conceptual model, design, code, test data and documentation, available reports, configuration management records) are made available when needed. The M&S PM should be involved in any discussions concerned with the exchange of information, data, software, tools, testing, etc. to prevent misunderstandings regarding access and rights to specific products as well as conclusions reached by the V&V Agent.

The M&S PM also serves as the main conduit of information from the V&V Agent to the other participants. All problems, results, and recommendations should be reported immediately to the M&S PM who, in turn should report them to the User, Accreditation Agent, and Developer, as appropriate. The V&V Agent should provide timely progress reports and make every effort to adhere to schedule, budget, and programmatic requirements deemed necessary by the M&S PM.

### ***V&V Agent's Relationship to the Developer***

The Developer and V&V Agent should have a clearly defined charter or contractual relationship that states what each can expect from the other. Moreover, as early as possible, they should establish a good working relationship that promotes information and data sharing and encourages close coordination between development and V&V plans and activities. The success of the V&V effort depends on access to development products and activities, (e.g., M&S requirements, conceptual model, software and hardware specifications, design artifacts, source and executable (object) code, drawings, data and databases, tools, support systems, configuration management data, test data, test results). In return, the Developer should expect the V&V Agent to provide immediate notification when problems are discovered and to make recommendations for their resolution, when possible. The Developer's problem reporting system should be used for this purpose because it generates a permanent record.

### ***V&V Agent's Relationship with the Accreditation Agent***

The relationship between the Accreditation Agent and the V&V Agent is critical for a successful and cost-effective VV&A effort. The Accreditation Agent should work with the V&V Agent to ensure that the V&V activities are sufficiently robust and focused to address all the accreditation needs. The Accreditation Agent serves as both a guide for and a customer of the V&V Agent. As a guide, the Accreditation Agent provides accreditation information requirements and V&V priorities to the V&V Agent to shape the V&V plan and process. As a customer, the Accreditation Agent receives information about the simulation's capabilities and limitations to use in the accreditation assessment.

The V&V Agent serves as primary support for the Accreditation Agent by collecting the majority of the evidence used in the accreditation assessment. The relationship between the V&V Agent and Accreditation Agent should be an on-going one of trust and cooperation so that both can be sure the evidence collected during the V&V effort will be sufficient to identify capabilities as well as the constraints of the simulation.

## ***V&V Agent's Relationship with Others***

### **Testing Activities**

The V&V Agent should coordinate with other participating testing activities<sup>55</sup> (e.g., OT, DT) to share resources and avoid unnecessary and redundant efforts. Both the M&S PM and User have the prerogative to bring in outside organizations to observe or evaluate the simulation, assist with the validation effort, test critical features and functions, or perform independent analyses to help determine the simulation's suitability and credibility. The V&V Agent should share information, reports, and assessment results with these groups at the direction of the M&S PM.

### **Subject Matter Experts**

Subject matter experts (SMEs)<sup>56</sup> are relied on throughout the V&V process to provide expertise in a variety of areas (e.g., operational doctrine, tactics, and procedures; software languages; data; physical and natural laws and relationships; hardware) during requirements verification and conceptual model and results validation activities. SMEs are also needed to help establish the validation testing requirements and identify "real-world" data used in results validation (i.e., validation data<sup>57</sup>). Normally, the User selects SMEs to participate in V&V activities that require expertise in the intended use (e.g., problem domain, User domain). The M&S PM is more likely to select SMEs to participate in activities requiring knowledge of the simulation or technical expertise in the simulation domain (e.g., software engineering, .computer specialists).

## **Documentation Requirements**

The M&S PM should require the establishment of a documentation archive, shown in [Appendix H](#), of essential VV&A information, ensuring that an accurate, comprehensive record of the development and V&V activities is preserved. This archive accomplishes several highly important functions. It provides the necessary evidence for initial accreditation, supports reuse of the M&S in the future, and provides source data that can be used by the Modeling and Simulation Resource Repository (MSRR) and other appropriate repositories to create the VV&A history for the M&S. The V&V Agent is responsible for collecting and preparing this documentation and information in a format

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<sup>55</sup> See the reference document on T&E and V&V Integration for additional information.

<sup>56</sup> See the special topic on Subject Matter Experts and VV&A for additional information.

<sup>57</sup> See the special topic on Data V&V for New Simulations for additional information.

that is easily accessed and sorted (e.g., high-level findings can be collected in a high-level V&V report). To be most useful, key pieces of information (e.g., the conceptual model) should be correlated with a particular version of the simulation and the documentation placed under configuration control. Subsequent changes should also be identified and the configuration managed in a similar manner.

The M&S PM's criteria for information collection and archiving should ensure that sufficient documentation is saved from each development phase to generate a complete profile of status, product quality and completeness, and identified problems and associated operational risks. All archived documents and reports should include their configuration management records. The archival schema should allow for sufficient documents and data to be transferred based on demand, without overwhelming the recipient. Small programs will likely eliminate some of these documents through tailoring. The following list reflects a traditional medium-sized development and V&V program. The set of archived items may vary for knowledge-based, human engineering, and object-oriented developments. The M&S PM and V&V Agent have the prerogative to specify the documentation to be archived.

<b>Candidate Documentation for a V&amp;V Archive</b>	
<b>Planning</b>	
<ul style="list-style-type: none"> <li>• All iterations of the V&amp;V plan</li> <li>• Accreditation plan</li> </ul>	
<b>Requirements Verification</b>	
<ul style="list-style-type: none"> <li>• Baseline requirements documents</li> <li>• Verification results</li> <li>• Requirements tracing database</li> <li>• Approved requirements</li> <li>• Acceptability criteria</li> <li>• Fidelity requirements and their assessment</li> <li>• Subsequent versions of the requirements tracing database and amended requirements</li> <li>• Records of changes (e.g., problem reports, change requests from the Developer's configuration management records)</li> <li>• Copies of all essential deliverables from the Developer</li> <li>• Reviews and feedback</li> </ul>	
<b>Conceptual Model Validation</b>	
<ul style="list-style-type: none"> <li>• Scenario assessment</li> <li>• Conceptual model validation evidence</li> <li>• Derived requirements</li> <li>• Conceptual model, including key algorithms, input data requirements, behaviors, mission and operational profiles, timelines, scenarios, representations, etc.</li> </ul>	
<b>Design Verification</b>	

<b>Candidate Documentation for a V&amp;V Archive</b>
<ul style="list-style-type: none"> <li>• Design documentation outputs of CASE tools</li> <li>• Design verification results</li> <li>• Requirements tracing documentation</li> <li>• Data model</li> <li>• Data verification documentation</li> <li>• Detailed algorithms ready for coding</li> <li>• Performance criteria</li> <li>• Timing templates</li> <li>• Functional testing results</li> </ul>
<b>Results Validation</b>
<ul style="list-style-type: none"> <li>• Requirements-to-test tracing</li> <li>• Data validation documentation</li> <li>• Development Test requirements</li> <li>• Validation test requirements</li> <li>• Test results</li> <li>• Validation results</li> </ul>
<b>Relevant Formal Reports</b>
<ul style="list-style-type: none"> <li>• Formal V&amp;V report(s) (usually generated in increments for a new simulation)</li> <li>• Copies of accreditation assessment results, report, and decision</li> </ul>

The V&V Agent should document and report accomplishments, successes, M&S capabilities, problems, and issues, both resolved and unresolved. This record is extremely important to the credibility of the current V&V effort and to future efforts. Providing accreditation support means having sufficient credible evidence to ensure good understanding of the capabilities and limitations of the simulation. High-level reports are normally not sufficient by themselves: they require detailed backup information for a full evaluation of the characteristics and capabilities of the simulation. Traceability is also essential to demonstrate how fully the M&S can address the needs of an application.

## **Cost Implications and Resourcing**

In the past, cost estimating for V&V programs has largely been based on coarse estimates of percentages of development cost, but this approach only works for new or recently completed M&S efforts. Even then, it is not very accurate. Unique attributes of each simulation tend to be ignored, and each estimate done in this manner is little better than an educated guess. A percentage-based estimate is not good enough by itself, because it does not consider size and programming languages, complexity, use cases, risk and uncertainty, unique characteristics of the simulation, or the maturity of the technology. Further, percentage-based estimates do not consider costs of SMEs, tools, support software and hardware, communications and networking, travel and TDY, etc.



Since cost estimation is multidimensional, the V&V estimate needs to consider a number of factors, such as those listed in the table below [Lewis, 2000].

Factors to Consider in V&V Cost Estimation
<ul style="list-style-type: none"> <li>• A clear understanding of the User needs and objectives for the M&amp;S</li> </ul>
<ul style="list-style-type: none"> <li>• A clear delineation of roles and responsibilities of each participant in the development effort and how organizational interfaces will operate</li> </ul>
<ul style="list-style-type: none"> <li>• The number of models or entities and how they are expected to interact in their configuration. This helps scope the magnitude and difficulty of the total effort</li> </ul>
<ul style="list-style-type: none"> <li>• Specific answers to questions about the M&amp;S requirements, conceptual model, and data quality<sup>58</sup></li> </ul>
<ul style="list-style-type: none"> <li>• Risk and uncertainty of the total program and how these factors affect the cost</li> </ul>
<ul style="list-style-type: none"> <li>• Estimated size of the software and its relative complexity (this helps bound the problem and provides sanity checking). Alternatives to source lines of code estimates can include function point counts, number of requirements, logical lines of code, etc.</li> </ul>
<ul style="list-style-type: none"> <li>• List of other direct costs (ODCs) for such items as tools, facilities, communications, SMEs, support software, travel, etc.</li> </ul>
<ul style="list-style-type: none"> <li>• Average man-hour, man-month, or man-year cost for the staff</li> </ul>

### ***What Constitutes a Good V&V Estimate?***

The terms “good,” “adequate,” “reasonable,” and “relatively accurate” in V&V cost estimating means that the activities and tasks outlined for the effort can be accomplished effectively and thoroughly, but costs will not be excessive. The **should-cost** figure is very important since it is the estimate of V&V costs produced independently of other inputs, influences, and outside budget constraints: it is what an adequately funded and supported V&V effort for the particular program should cost. Ideally this will be the V&V budget. If conditions change during the development of the simulation, this estimate should be reviewed to ensure it still correctly represents the required effort.

[Leveraging](#) is a significant cost-reduction technique; however leveraging also increases program risk slightly because the V&V Agent is relying on the information and work provided by others. If the work appears marginal or doesn’t focus squarely on the requirements, then the V&V Agent should be prepared to either redo the task, return it with comments and questions, or pursue an alternative path with the concurrence of the M&S PM. Information collected as evidence for accreditation should pass the scrutiny of a V&V review without unresolved questions.

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<sup>58</sup> See the RPG templates on Data Quality for additional information.



Sometimes the M&S PM or User has a preconceived cost figure in mind that differs widely from the systematically produced estimate. Sometimes this figure is above the should-cost figure, but more often it is below it. Unfortunately, this “shoot from the hip approach” can result in overfunded V&V efforts that lead to criticisms of the high costs, and it can result in underfunded V&V efforts that are criticized for not doing everything that needed to be done. Either way, the V&V program suffers from the lack of scientific cost estimating. The estimating principles discussed here may prevent “extreme” estimates from being generated in the first place.

### ***The Challenges of Exceptional Validation Needs***

Some aspects of a simulation may be difficult to validate for a number of different reasons, most of which are based on assumptions that either the phenomena or physical properties of the things being modeled are too complex or the highly stochastic nature of the outcome is too nebulous to provide accurate and consistent measurements. These aspects are often termed “exceptional” because their complete validation would either involve excessive time or excessive resources. Most modeling situations involving exceptional validation issues can be successfully managed and supported by effective VV&A efforts as long as the User recognizes the limitations and constraints imposed on the results. One approach is to systematically divide the problem space into parts that can be effectively and reasonably validated and those that cannot. Validation and test results and other evidence should be collected using traditional validation and testing techniques for as much of the problem space as possible, while a team of SMEs and other experts is convened to perform face validation and possibly some advanced statistical analysis on the more difficult remaining parts of the simulation or model.<sup>59</sup>

The V&V Agent has to recognize the point of diminishing returns and try to stop just short of it. Whatever cost estimating process is used should have built-in checks and balances so the User or M&S PM can readily see what the V&V effort is proposing to do for the assigned budget. If the V&V effort in specific task areas needs to be increased to help overcome exceptional validation issues, this can be accomplished in one of two ways:

- **Option 1.** Exceptional validation tasks, their level of effort (LOE), and costs are included in the validation cost estimate, but are tracked separately. This is the preferred method, because it does not impact other V&V tasks, it does provide a reasonable V&V plan and cost estimate, and it still allows all of the exceptional validation activities to be tracked, managed, and accounted for separately.
- **Option 2.** Exceptional validation activities can be rolled into the pre-defined validation activities by maximizing the budget through tailoring and adjusting the estimate. However this does involve more effort by of the planner, who must

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<sup>59</sup> See the reference document on V&V Techniques for a synopsis of 76 different techniques.

enter data, examine the results, and tune the estimate until the correct answer is derived.

Both options require that the V&V planners prepare a separate estimate for exceptional validation support; however, it would be much easier to incorporate this estimate using Option 1. Regardless of the option used, the V&V planner is cautioned to avoid being carried away with an overly ambitious validation effort. If the simulation has been built, but the validation looks very difficult, there may be flaws in the assumptions about how to perform the validation effort or about what must be done to demonstrate the simulation's fitness for the current application. Full cooperation is required among all the participants to come up with a balanced, leveraged, and cost-effective validation plan and estimate.

If the M&S PM and User accept the V&V plan with the levels of effort proposed and the V&V Agent performs the specified work, yet unreconciled validation objectives remain, it may be that the goals were unrealistic within the available resources. Use of outside agencies, SMEs, and budget increases to extend the validation effort are all possible options. Option 1 above is also preferred when these shortcomings in the validation effort are discovered during testing. It is easier to add a separate task than to rework the entire V&V plan and estimates.

There will always be a few isolated examples of exceptional validation problems that require serious planning, study, and collaboration among the M&S PM, Developer, User, and V&V Agent to come up with reasonable, workable solutions. A final thought involving difficult validation problems is that all the testing conducted by all the participants combine to form the basis for validation. The V&V Agent needs to be able to pull from all these sources whatever is most germane to the ultimate fitness of the simulation for the intended use. To this end, sometimes the best solution is knowing where to stop. This decision should be reached mutually by all the participants in the program so that everyone agrees, and no single group feels burdened by too much responsibility for the success of the program.

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## ***RPG References in This Document***

- select menu: *RPG Core Documents*, select item: "Accreditation Agent Role in the VV&A of New Simulations"
- select menu: *RPG Core Documents*, select item: "M&S PM Role in the VV&A of New Simulations"
- select menu: *RPG Reference Documents*, select item: "M&S Data Concepts and Terms"
- select menu: *RPG Reference Documents*, select item: "A Practitioner's Perspective on Simulation Development"
- select menu: *RPG Reference Documents*, select item: "T&E and V&V Integration"
- select menu: *RPG Reference Documents*, select item: "V&V Techniques"
- select menu: *RPG Reference Documents*, select item: "V&V Tools"
- select menu: *RPG Special Topics*, select item: "Conceptual Model Development and Validation"
- select menu: *RPG Special Topics*, select item: "Data V&V for New Simulations"
- select menu: *RPG Special Topics*, select item: "Fidelity"
- select menu: *RPG Special Topics*, select item: "Human Behavior Representation Validation"

select menu: *RPG Special Topics*, select item: "Measures"

select menu: *RPG Special Topics*, select item: "Paradigms for M&S Development"

select menu: *RPG Special Topics*, select item: "Problem Analysis"

select menu: *RPG Special Topics*, select item: "Requirements"

select menu: *RPG Special Topics*, select item: "Risk Assessment and Its Impact on VV&A"

select menu: *RPG Special Topics*, select item: "Subject Matter Experts and VV&A"

select menu: *RPG Special Topics*, select item: "V&V Cost Estimating"

select menu: *RPG Special Topics*, select item: "Validation"

select menu: *RPG Templates*, select item: "Data Quality Templates"

select menu: *RPG Templates*, select item: "VV&A Planning and Report Templates"

*In the web-based version of this document, the appendix below appears as a hot link in the section What Challenges Does the V&V Agent Face.*

## Starting the V&V Effort

The most cost-effective and appropriate time to begin a V&V effort for a new simulation is at the beginning of its development. This is not the beginning of the M&S program; rather, it is when the User has already made the decision to build a new simulation, has determined its overall concept and requirements, has an approved program, and has committed funding. In other words, all the essentials are in place for the M&S PM to be appointed, the Developer to be selected, and the Accreditation Agent to be designated. If the Developer is a contractor, there may be a delay while the contract is being awarded. However, the User, Accreditation Agent, and M&S PM can conduct the problem analysis and risk assessment that result in the identification of priorities and acceptability criteria.<sup>1</sup> The V&V effort should not begin until the development effort starts because the V&V effort depends very heavily on many development factors and contractual issues.

The User and M&S PM can initiate the V&V planning before the V&V Agent is brought on board, or the M&S PM can direct the V&V Agent to do the planning, often during the proposal stage, when the draft V&V plan is included as an exhibit in the proposal. In either case, once the V&V effort begins, any such plans should be subject to modification because the V&V plan cannot be made firm until the M&S requirements and the Developer's detailed planning are relatively complete. Thus, it is a commonly accepted practice for the V&V effort to begin operating from a draft plan that is put into final form as late as the conceptual modeling phase in order to better meet the specific needs of the program.

### ***Delayed Appointment of the V&V Agent***

In some instances, a V&V Agent is not designated until some time after the start of the development. This results in a situation in which one of several alternatives may occur.

- **Developer performs requirements verification.** This approach is successful with the verification activities and requirements tracing are carefully and completely documented. The V&V Agent reviews all information provided and conducts any activities needed to ensure the information provided is accurate and sufficient.
- **V&V Agent performs the requirements verification in retrospect.** This approach loses much of its cost-effectiveness and puts the V&V Agent in a mode of "making up for lost time"; however, it does establish the foundation for all later testing and V&V activities.

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<sup>1</sup> See the special topics on Problem Analysis and Risk and Its Impact on VV&A for additional information.

- **The missed activities are skipped.** This is much like putting a building up without a foundation and should be discouraged.

Whenever the V&V Agent begins, the challenge is to establish appropriate interactions immediately within the current phase of development and to tailor the V&V planning to ensure that V&V activities associated with earlier development phases are discussed with the PM to determine an appropriate form of remediation using the most effective means available. Neither the development nor the V&V effort can function effectively without verified, consistent, complete requirements, since the conceptual model and simulation design are based on them.

When someone else has performed the initial V&V activities, the V&V Agent should review all the activities and results to ensure their completeness, correctness, and appropriateness. This alternative also results in some delay. In these situations, the V&V Agent should adjust the V&V plan to ensure that delayed V&V activities are caught up by the most efficient means available. This may involve using alternative methods such as calling in tiger teams, SMEs, and domain experts.

When the V&V effort begins late, all make-up activities should be done quickly and, for the most part, concurrently with other V&V activities. The V&V Agent has to consider that the added factor of delay may restrict the choice of techniques and tools that can be used.

Requirements verification and other early V&V processes cannot be skipped completely because the information obtained from them is used to determine the completeness and appropriateness of later development phases.

*In the web-based version of this document, the appendix below appears as a hot link in the two sections: What Challenges Does the V&V Agent Face and Develop V&V Plan.*

## **An Adequate V&V Plan**

At the beginning of the V&V effort, the most significant task is the development of a plan that defines the necessary activities and tasks to the level that they can be assigned to V&V personnel and executed. There is a delicate balance between too little and too much detail. Too little detail is marked by generalizations such as “perform requirements verification”. Conversely, too much detail can result in a rigid procedure that prevents the V&V practitioner from responding to problems and adjusting to changes in the development as needed. Generally, the appropriate level of planning detail is to identify the V&V tasks needed in each development phase to enable the development to proceed to the next phase.

Because a significant part of the V&V plan depends on the M&S requirements,<sup>1</sup> their associated metrics and acceptability criteria, and the risks associated with each, V&V planning and requirements verification activities are usually performed concurrently. Results of the problem analysis<sup>2</sup> and risk assessment<sup>3</sup> (normally conducted by the User with support from the M&S PM, Developer, Accreditation Agent, and V&V Agent) identify the high-risk areas and priorities upon which the V&V effort should focus. These help determine the scope and magnitude of the V&V effort. Effective planning also depends heavily on having a comprehensive understanding of the development effort and of the expectations of the M&S PM and the Accreditation Agent.

Other considerations during planning include coordinating schedules with the development effort, staffing, establishing good working relationships with other participants, selecting the most effective and practical techniques and tools to accomplish the necessary V&V activities, and estimating costs. Costs of tools, support equipment, and software are usually handled as a separate line item in the V&V effort to avoid co-mingling labor costs with other direct costs (ODCs). Any other additional costs, such as SMEs needed to assist in the V&V effort, should also be added to the ODCs.

A V&V plan should include the basic information elements shown in the table below. This table can be used as an outline for generating a V&V plan; however, the contents of the plan should be tailored to the precise needs of the program involved by removing elements that do not apply, adding or modifying elements so they do, and by adding specificity. In addition, a V&V plan should accommodate the format and content requirements of the individual Services, Agencies, and organizations involved.<sup>4</sup>

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<sup>1</sup> See the special topic on Requirements for additional information.

<sup>2</sup> See the special topic on Problem Analysis for additional information.

<sup>3</sup> See the special topic on Risk and Its Impact on VV&A for additional information.

<sup>4</sup> See the RPG VV&A Planning and Report Templates for additional information.



Basic Content of a Typical V&V Plan	
• Purpose and description of the V&V effort	
• Scope of the V&V effort and responsibilities	
• Identification of the participants and the responsibilities of each:	
– M&S PM	
– User	
– M&S Developer (who, where, facility descriptions, etc.)	
– Accreditation Agent	
– Additional testing agencies (e.g., Operational Test Authority [OTA])	
– SME list (may be added to and modified over time)	
– V&V staffing plan by month	
• Intended use(s) or application of the simulation	
• V&V schedule based on Developer's schedule	
• Information needed:	
– Development products and processes to be shared with V&V	
– Data sources and metadata	
– Information about the user and problem domains	
• Description of Developer's configuration management system and how it will be used for V&V	
• Description of the V&V process model used	
• V&V techniques and methods matched to development paradigm:	
– Verification processes in context of planned simulation development. Defines the activities to be completed for each development phase. Provides descriptions of verification tasks to be performed.	
– Validation processes in context of planned simulation development. Defines the activities to be completed for each development phase. Provides descriptions of validation tasks to be performed.	
• Validation data to be used during results validation; data sources and plans for obtaining and reducing this data	
• Tools:	
– Development tools to be shared with V&V	
– V&V tools	
– Tool use (V&V and development) by phase for complementary and unique applications	
• V&V products and deliverables	
• V&V reporting procedures, reports, formats	
• V&V baseline (approved) budget	
• V&V ODCs list (e.g., costs of special software and hardware, tools, special testing, communications, SMEs, travel)	
• Description and locations of V&V archives to support accreditation and future reuse	
• Appendices (as required)	

*In the web-based version of this document, the appendix below appears as a hot link in the section What Challenges Does the V&V Agent Face.*

## Adequate V&V Funding

Once the V&V activities and tasks for each development phase have been identified and defined in terms of their relative level of effort, the labor and other direct costs (ODCs) can be estimated. When an adequate estimate is derived, the M&S PM will probably discuss the proposed tasks with the V&V Agent and negotiate the funding of the V&V effort. This may require some compromises from both parties, since it is possible that the “should cost” estimate from the V&V planning exercise may have to be further tailored to converge with available funding, as well as with the desires of the M&S PM and User.

Trade-offs should always be based on return on investment (ROI) and the prioritization of the proposed tasks to determine the set that is acceptable to both parties and that can still support the credibility, risk mitigation, and accreditation needs of the M&S program. When budget shrinkage means that these essential V&V tasks can no longer be supported, the development and accreditation risks both rise sharply. The M&S PM must consider all options, including increasing the budget and the amount of leveraging from the development effort in order to provide an adequate program.

### ***Underfunding***

V&V funding is sometimes allocated at the beginning of an M&S development program before the actual requirements are defined, and often before the V&V Agent has been selected. This frequently results in estimates derived from rule-of-thumb calculations or best-guess estimates. These estimates are notoriously poor and can be either well above or well below estimates derived from a more scientific process. Because of the tendency to guess at a number early in the program and continue to use it, is not uncommon to find that the carefully planned and derived “should cost” figure and the available funding are more than 10% apart. The most practical solution is to examine all the primary cost factors and prioritize them by assessing their expected ROI versus the risk they represent. V&V costs can be reduced in a variety of ways once the task priorities have been established. A few of the common ways to reduce V&V cost are shown in the table below:

Possible V&V Cost Reduction Techniques
Activities
<ul style="list-style-type: none"><li>• Prioritize all V&amp;V activities and eliminate those with lowest payoff</li></ul>
<ul style="list-style-type: none"><li>• Combine tasks where possible, but be cautious because combining may have the reverse effect of making the new item harder to maintain</li></ul>
<ul style="list-style-type: none"><li>• Perform critical tasks concurrently to reduce labor and assessment time</li></ul>

<ul style="list-style-type: none"> <li>• Reduce the number of tests in which V&amp;V Agent participates</li> </ul>
<ul style="list-style-type: none"> <li>• Reduce level of effort on the lower priority activities</li> </ul>
<ul style="list-style-type: none"> <li>• Focus more on leveraging in the design and implementation phases as well as during testing</li> </ul>
<ul style="list-style-type: none"> <li>• Focus more on the items that are essential to the accreditation effort</li> </ul>
<b>Tools</b>
<ul style="list-style-type: none"> <li>• Look for and use lower priced analysis tools than those in the original plan and budget, provided that capability is not unduly compromised (be cautious with this approach)</li> </ul>
<ul style="list-style-type: none"> <li>• Use the developer's tools more than originally planned</li> </ul>
<ul style="list-style-type: none"> <li>• Select fewer seats (copies) for those tools that are purchased; this saves hardware and software costs</li> </ul>
<ul style="list-style-type: none"> <li>• Use a more powerful automated tool to accomplish more work than can be done with manual methods or alternative tools (be cautious with this approach)</li> </ul>
<ul style="list-style-type: none"> <li>• Use manual methods where they do not negatively impact the analysis, schedule, or resources</li> </ul>
<b>Personnel</b>
<ul style="list-style-type: none"> <li>• Reduce the number of V&amp;V personnel attending out-of-town meetings</li> </ul>
<ul style="list-style-type: none"> <li>• Do more teleconferencing rather than traveling</li> </ul>
<ul style="list-style-type: none"> <li>• Share SMEs with the development effort. Solicit low-cost or free SMEs from the User who is sponsoring the M&amp;S development</li> </ul>
<ul style="list-style-type: none"> <li>• Reduce the number of staff assigned to specific noncritical tasks</li> </ul>

*In the web-based version of this document, the appendix below appears as a hot link in the section What Challenges Does the V&V Agent Face.*

## Selecting the Right People

The realm of simulation is as varied as the real-world systems and entities that are being simulated; therefore, the selection of people with the right skills involves considering two questions: What is being modeled? and, How is the simulation to be used? Answering these two questions begins with the process of focusing on the right mix of skills.

**Examples:**

- A person whose experience is centered in discrete event campaign modeling used for training may not be effective in the real-time missile performance domain.
- A missile expert may not have sufficient understanding of the large view to plan and execute appropriate validation tests of a campaign simulation.

The V&V planners should select people with specific skills that match each task involved. Because all the needed skills are seldom available in a single individual, the “V&V Agent” typically includes a team of specialists, some of whom will be phased in and out as needed.

It is important to remember the differences between verification and validation when staffing these positions.

- Verification focuses on the integrity and functionality of the requirements, design, and implementation of the hardware and software. Those who perform design or implementation verification activities, in particular, should have experience with hardware and software development and integration, much of which is not essential in the validation effort.
- Validation focuses on the real-world representations, performance, operational aspects, behaviors, interactions, and fidelity of the M&S. Those who perform validation should have strong analytical and operational backgrounds, especially in the systems being modeled and in the domains of interest.

Some of the special skills needed are shown in the table below:

Characteristics of V&V Personnel
<ul style="list-style-type: none"><li>• Knowledge of and experience with similar types of models and simulations</li></ul>
<ul style="list-style-type: none"><li>• Knowledge of and previous experience with the systems being modeled</li></ul>
<ul style="list-style-type: none"><li>• Extensive knowledge of the domains involved (i.e., problem, user, simulation)</li></ul>

Characteristics of V&V Personnel
• Familiarity with selecting and using appropriate automated tools
• Ability to specify and use facilities and equipment
• Familiarity with the software languages and hardware platforms being used
• Modeling and simulation development experience and skills
• Solid analytic skills
• Willingness to accept a wide variety of challenges
• High degree of technical curiosity

In addition, the V&V effort often involves the temporary assistance of subject matter experts (SMEs)<sup>1</sup> for various activities:

- Military analysts are frequently called upon to evaluate applications involving warfare operations from their personal fields of expertise
- Analysts who assisted the User in defining the requirements may also be asked to participate in conceptual model validation to ensure that the requirements have been appropriately incorporated in the conceptual model
- Experienced M&S developers with appropriate domain background may be asked to assist with design or implementation verification
- Any person with a specialized skill may be asked to assist with a V&V task needing that skill

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<sup>1</sup> See special topic on Subject Matter Experts and VV&A for additional information.

*In the web-based version of this document, the appendix below appears as a hot link in two sections: What Challenges Does the V&V Agent Face and Validate Results.*

## V&V Tool Selection

The V&V Agent should have a solid understanding of the development effort before selecting tools for the V&V effort. Typical information needed by the V&V Agent includes:

- **Development Paradigm.** The type of development paradigm<sup>1</sup> used affects the types of tools to be used. The number of repetitions and duration of the cycles affect the cost-effectiveness, utility, and types of the tools.
- **Development Process.** The tools selected for the V&V effort need to be compatible with the tools used in the development process (e.g., object oriented (OO), structured (functional)).
- **Development Schedule.** A short schedule means highly efficient tools are needed with short learning curves, or perhaps use of a tool vendor. Longer schedules can permit use of lower-cost, less-integrated tools and still accomplish similar results.
- **Development Environment Tools.** Large-scale, highly integrated CASE tools are costly but have many inherent verification features that promote leveraging. High cost is likely to prevent the V&V Agent from duplicating them. A less integrated tool environment is usually cheaper and gives V&V Agents more opportunities to use their own tools for complementary assessments. The degree of integration of tools in the development environment is a key influence on V&V tool selection. Does the Developer use one big multi-phase tool or lots of smaller ones?
- **Development Integration and Testing.** The Developer's strategy in integrating and testing software and hardware products has a large effect on the tools needed to monitor, control, and drive the testing. The V&V Agent has to determine how to fit into this process and identify the tools needed to support validation.

Once the V&V Agent has the necessary information about the development, the types of tools needed for specific V&V tasks should be determined. Candidate tools should be identified and cost-benefit analysis conducted. A number of factors, such as those shown in the table below, should be considered in this analysis. For example, large, highly integrated CASE tools may be fine for development, but may be too expensive and difficult to use, and that may require excessive training and special hardware to be cost-effective for the V&V effort.

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<sup>1</sup> See the special topic on Paradigms for M&S Development for additional information.

Tool Selection Factors	
<b>Compatibility with development tools</b>	<ul style="list-style-type: none"> <li>• V&amp;V tools need to work with or at least be compatible with the development tools to yield believable results.</li> </ul>
<b>Initial and ongoing maintenance costs</b>	<ul style="list-style-type: none"> <li>• Cost to the V&amp;V effort is a very large consideration since resources are much more limited than for the development.</li> </ul>
<b>Training costs</b>	<ul style="list-style-type: none"> <li>• Large, expensive tools require extremely high training costs, making them difficult for the V&amp;V effort to afford.</li> </ul>
<b>Availability and maturity</b>	<ul style="list-style-type: none"> <li>• V&amp;V should go for mature, readily available tools as opposed to buying tools that are still evolving and possibly unstable. However, avoid tools that are becoming obsolete.</li> </ul>
<b>Resource requirements</b>	<ul style="list-style-type: none"> <li>• V&amp;V Agent should first consider tools that run on available hardware platforms and avoid buying additional hardware just to run a particular tool unless absolutely necessary.</li> </ul>
<b>Time constraints</b>	<ul style="list-style-type: none"> <li>• If the tool requires long setup and input preparation time, avoid it and select one that does not.</li> </ul>
<b>Flexibility</b>	<ul style="list-style-type: none"> <li>• Look for tools that cover more than one specific task and that can work with more than one software language, etc.</li> </ul>
<b>Ease of use</b>	<ul style="list-style-type: none"> <li>• Select the tools that are the easiest to use and that give results quickly. An 85% solution arrived at quickly is usually better than a 97% solution arrived at too late.</li> </ul>
<b>Required accuracy and capabilities</b>	<ul style="list-style-type: none"> <li>• Buy the simplest, fastest, cheapest tools that provide the necessary accuracy and capabilities for the tasks at hand.</li> </ul>

The budget allocated for a V&V program does not usually allow purchase of a large number of tools, nor does the schedule usually allow time for long training in their use. The goal should always be to select the most cost-effective set of essential tools. The V&V Agent should work with the Developer and M&S PM to determine what tools can be shared and what tools need to be copied for the V&V effort.

When a V&V function requires a specific type of tool to perform code analysis, it may be more cost-effective to use the services of a tool vendor offering a service bureau function than to acquire the tool and train V&V staff on its use. Using such a tool can be a highly specialized skill, requiring extensive experience, so the use of an outside vendor to provide this service is highly recommended.

**Example:**

A V&V effort was responsible for reviewing and assessing a half-dozen sequential software releases over a 1-year period on an important project with a very tight budget. The job looked impossible because there was too little money in the budget to purchase an appropriate code analysis tool and to train people in its use. The solution was to contract with a tool vendor to have them use their analysis tool for the rapid assessment of each release. The V&V Agent then analyzed the results and identified specific areas needing attention. Turnaround time for each assessment was less than 2 weeks; several critical software problems plaguing the project were uncovered and recommendations for fixes provided to the Developer.

See the reference document on V&V Tools for additional information.





*In the web-based version of this document, the appendix below appears as a hot link in the section Develop V&V Plan.*

## Tailoring and Leveraging

A truly cost-effective V&V effort seeks to balance the requirement for simulation credibility and risk reduction with the real-world constraints of development schedules and resources. Examples of V&V tailoring and leveraging issues are shown in the table below:

Tailoring and Leveraging Issues	
<ul style="list-style-type: none"> <li>• <a href="#">Is the Developer preparing a requirements tracing database?</a></li> <li>• Does it require review?</li> </ul>	<ul style="list-style-type: none"> <li>• A “no” answer means that the V&amp;V Agent will need to prepare a requirements tracing database</li> <li>• If there is one, it will require review.</li> </ul>
<ul style="list-style-type: none"> <li>• <a href="#">Is the Developer preparing an adequate formal conceptual model?</a></li> <li>• Does it require review?</li> </ul>	<ul style="list-style-type: none"> <li>• A “no” answer means the V&amp;V Agent needs to play a larger role in improving the conceptual model</li> <li>• If there is one, it will require review</li> </ul>
<ul style="list-style-type: none"> <li>• <a href="#">Does the simulation have any external interfaces?</a></li> </ul>	<ul style="list-style-type: none"> <li>• Interfaces may require additional design assessment and testing, depending on the results of an application risk analysis</li> </ul>
<ul style="list-style-type: none"> <li>• <a href="#">Will the verification activities involve static and dynamic code analyses?</a></li> </ul>	<ul style="list-style-type: none"> <li>• Code analysis can be expensive</li> <li>• The level of application risk can help determine if this effort is needed</li> </ul>
<ul style="list-style-type: none"> <li>• <a href="#">Which paradigm is being used in the development?</a> <ul style="list-style-type: none"> <li>– Waterfall</li> <li>– Incremental</li> <li>– Evolutionary</li> <li>– Prototyping</li> <li>– Spiral</li> <li>– Other (knowledge-based system [KBS], human engineering [HE], etc.)</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Incremental development tends to stretch out the V&amp;V effort, resulting in greater cost or diminished scope</li> <li>• Effort may have to increase toward the end of the effort</li> </ul>

### Is the Developer preparing a requirements tracing database?

#### Example:

If the Developer prepares a requirements tracing database, the V&V Agent reviews it for content, completeness, adequacy, and organization. This is a low level of effort (LOE) task if everything is found to be in good shape. It becomes a moderate LOE task if the V&V Agent finds problems such as incomplete references, discrepancies, etc. If there is no tracing database and the Developer is not required to prepare and maintain one, the burden falls on the V&V effort, and it is a high LOE task.

### **Is the Developer preparing an adequate formal conceptual model?**

The assumption should be that the Developer will prepare a conceptual model. The problem for the V&V effort is to determine completeness and adequacy. If this conceptual model follows the guidelines in this RPG, its review will be a low to moderate LOE task. However, if it does not, and it has significant shortcomings, its review and improvement becomes a high LOE task.

### **Does the simulation have any external interfaces?**

External interfaces mean additional V&V effort. They introduce the need for a number of additional V&V tasks.

### **Will the verification activities involve static and dynamic code analyses?**

Some Developers run their code through software analysis tools and some do not. If the Developer does not do so, then the application risks associated with the intended use should be analyzed to determine if this level of effort is needed. If so, the analyses may be subcontracted to a company that specializes in performing this type of service. Frequently, this is a more cost-effective solution than buying a tool, training the V&V personnel, and losing valuable time with learning to use the tool.

### **Which development paradigm is being used in the development?**

The development paradigm<sup>1</sup> used affects the level of development risk, as well as development costs and scheduling, which, in turn, affect the V&V effort. Even though incremental and evolutionary development paradigms tend to reduce development risk, they also tend to increase overall development costs. Most of this added cost is driven by the longer schedules, fixed overhead costs, and repetitious work in which some throwaway software and even hardware might be produced. Therefore, the V&V effort will typically cost more for incremental M&S development programs.

In addition, the various development approaches that might be selected (e.g., object oriented (OO), knowledge based systems (KBS), and human engineering (HE)) are different enough to change many of the development processes and artifacts significantly.

The issues discussed above are examples of the basic issues to be addressed during V&V planning in most simulation development efforts. Because each simulation development effort is unique, additional issues about the specific development will need to be addressed during V&V planning so that an appropriate LOE can be established [Lewis, 2000].

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<sup>1</sup> See the special topic on Paradigms for M&S Development for additional information.

*In the web-based version of this document, the appendix below appears as a hot link in the section Other Considerations.*

## Support Tools

Because of the complexity of some simulations, the Developer's software tools may need to be shared with the V&V effort. The V&V Agent may also have to select separate tools to develop different perspectives and information relating to credibility and quality of the simulation. This is especially true in testing and validating the simulation in which the test facility has to be shared. These facilities usually include data logging and reduction, analysis capabilities, test drivers, and visualization capabilities. Sometimes the V&V Agent becomes an adjunct to the test community that uses this facility, since it is usually not economically feasible for the V&V effort to recreate the exact conditions and configurations that are present therein. When this facility is shared, the M&S PM has to make sure that priorities are carefully managed and controlled to keep conflicting use requirements to a minimum.

The V&V effort needs its own tools. Just as there are no perfect models, there are no perfect tools. Thus, the V&V Agent needs to select separate tools carefully to complement those used in developing the simulation so that defects left undetected by the Developer's tools can possibly be caught by a different V&V tool. The V&V team may include a software tool expert who can assist in the selection and application of complementary tools. This function has a strong influence on the return on investment (ROI) and efficiency of the V&V effort.

*In the web-based version of this document, the appendix below appears as a hot link in the section Documentation Requirements.*

## Appendix H: VV&A Archive Information

The following table lists some of the major artifacts and products to be archived for future VV&A efforts.

Information to Consider Archiving for VV&A	
Development Phase	Products and Information
<b>M&amp;S Requirements</b>	<ul style="list-style-type: none"> <li>• definitions</li> <li>• metrics, measures,<sup>1</sup> and acceptability criteria</li> <li>• requirement trail through the conceptual model and design to code</li> <li>• relationships to specific entities, processes, behaviors, events, or outputs</li> <li>• modifications/revisions required and accomplished</li> </ul>
<b>Planning</b>	<ul style="list-style-type: none"> <li>• problem definition and objectives</li> <li>• M&amp;S development plan</li> <li>• V&amp;V plan</li> <li>• accreditation plan</li> <li>• modifications/revisions required and accomplished</li> </ul>
<b>Conceptual Model</b>	<ul style="list-style-type: none"> <li>• validated annotated conceptual model</li> <li>• behaviors and interactions<sup>2</sup> and associated data</li> <li>• sources of real world knowledge, data</li> <li>• verification techniques and results (e.g., data sources, interactions)</li> <li>• validation process and results (e.g., behaviors, conceptual model)</li> <li>• modifications/revisions required and accomplished</li> </ul>
<b>M&amp;S Design</b>	<ul style="list-style-type: none"> <li>• annotated simulation design, preliminary and detailed</li> <li>• design entities (e.g., objects, attributes, parameters) mapping to conceptual model elements, objectives, requirements</li> <li>• verification techniques and results (e.g., functionality)</li> <li>• modifications/revisions required and accomplished</li> </ul>
<b>Implement and Test</b>	<ul style="list-style-type: none"> <li>• verified code</li> <li>• verification techniques and results (e.g., data, code)</li> <li>• testing techniques, data, scenarios (use cases), and results</li> <li>• data flow analysis</li> <li>• validation techniques, data, algorithms, scenarios (use cases), and results</li> <li>• modifications/revisions required and accomplished</li> </ul>

<sup>1</sup> Measures of Performance (MOPs), Measures of Effectiveness (MOEs), etc. used to quantify each requirement. See the special topic on Measures for additional information.

<sup>2</sup> For example, the interaction of wind over the wing of an aircraft causing the aircraft to follow the laws of physics or tracing how command and control decisions are made (working backward from decision tables through to the sources of the information).

Information to Consider Archiving for VV&A	
Development Phase	Products and Information
Prepare for Use	<ul style="list-style-type: none"><li>• accreditation information needs</li><li>• accreditation assessment process, results, and recommendations</li><li>• accreditation report</li><li>• modifications/revisions required and accomplished</li><li>• constraints, limitations, assumptions associated with the application</li><li>• results of execution</li></ul>

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